STATE OF ALASKA

William A. Egan, Governor

Annual Progress Report for

A Study of Land Use Activities and their Relationship to the Sport Fish Resources in Alaska

by

Steven T. Elliott

and

Richard Reed

ALASKA DEPARTMENT OF FISH AND GAME

James W. Brooks, Commissioner

DIVISION OF SPORT FISH

Rupert E. Andrews, Director

Howard E. Metsker, Coordinator

PREFACE

This year concludes the first full year of field activities to be conducted under the Land Use Study (D-1). This report does not, however, present the initial information which has been collected on the effects of logging on fish habitat.

Initial research into logging effects on rearing fish habitat was started under the Dolly Varden Study (R-IV). In 1970, it was decided that research was necessary to determine what effects logging operations have on the stream habitat needed by the Dolly Varden, Salvelinus malma, during their freshwater rearing stages. As a result, a separate job entitled, Effects of Logging on Dolly Varden (R-IV-B), was initiated under the Dolly Varden study.

After two years of research, the major emphasis no longer rested solely with Dolly Varden, but had expanded to include all rearing salmonids. In addition, it was felt that a broader scope of study, covering all phases of land use activities, rather than solely logging operations, was necessary. Consequently, it was recommended that the effects of logging research be removed from the Dolly Varden Study and a new overall Land Use Study be established. The following reports cover the initial activities conducted under this new study.

ANNUAL REPORT OF PROGRESS

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RESEARCH PROJECT SEGMENT

State: Alaska

Project No.: F-9-5 Name: Sport Fish Investigations of Alaska

Study No.: D-I Study Title: A Study of Land Activities and Their Relationship to the Sport Fish Resources in Alaska.

Job No.: D-I-B Job Title: Ecology of Rearing Fish

Period Covered: July 1, 1972 to June 30, 1973.

ABSTRACT

Wire mesh minnow traps were tested as a device for determining population estimates, population indexes, and species composition of rearing Dolly Varden *Salvelinus malma*, and coho, *Oncorhynchus kisutch*, populations in small streams.

Analysis of length frequencies of juvenile Dolly Varden and coho revealed that minnow traps are size selective and seldom capture coho smaller than 41 mm and Dolly Varden less than 61 mm.

It was found that minnow traps serve as a poor method for determining population indexes as they do not capture a consistent percentage of the rearing fish community.

Minnow traps were shown to be a reliable method of determining the species composition of rearing communities.

The effectiveness of the back-pack electrofisher to assess fish population was also evaluated and it was found that catches made by repetitive shocking in an enclosed stream section were similar to the results obtained through the use of Peterson estimates.

Results of experiments determining the feasibility of minnow traps as a population estimating device were not adequate and no conclusions could be drawn from the data.

Aquatic insect surveys of 29 stream and river systems were compiled and a provisional list of S. E. Alaskan aquatic insects was constructed.

An annotated bibliography on rearing salmonids in streams, containing 93 citations, was compiled.

RECOMMENDATIONS

Field surveys conducted in 1971-72 of logged areas in southeast Alaska indicated that there are many streams that have been damaged by debris and slash from logging operations (Reed and Elliott, 1972). In many cases, slash and debris completely cover stream channels indicating that some type of debris removal may be necessary to restore streams to their original condition.

Since little is known about the degree of removal necessary to restore rearing fish habitat, we feel that a study to determine the effects of debris removal is needed if these areas are to be restored to their optimum production.

Past research (Hood Bay Creek, Alaska) suggests that juvenile Dolly Varden and coho move upstream to warm, spring-fed tributaries to overwinter (Blackett, 1968). These movements may be an attempt to escape severe icing conditions in the main-stream. Temperature studies at Hood Bay Creek have revealed that the spring-fed tributaries maintain a yearly temperature of 41-43^{o}F while the mainstream freezes (Elliott and Armstrong, 1972).

To gain a better understanding of salmonid rearing requirements during the winter, we feel that a study to determine the role of overwintering areas would be of benefit.

The effects of canopy removal on summer stream temperatures has been well documented in the literature, but there is little information relating canopy removal to winter temperatures. Green (1950) indicates that lower temperatures are experienced during the winter in exposed streams which may cause detrimental ice conditions and delay development of incubating salmon eggs. It is possible that removal of overstory around small streams may decrease the water temperature in small rearing streams that are vital as overwintering areas.

We feel that a study of the effects of canopy removal on winter stream temperatures would contribute to the overall understanding of rearing fish ecology and supply needed information for recommendations concerning land use activities.

Future studies on the Ecology of Rearing Fish, using the data collected this field season as baseline information, should include the following objectives:

1. Determine the feasibility of conducting a study on the effects of debris removal on fish populations in small streams.

2. Determine the feasibility of conducting research on the importance of spring-fed tributaries for overwinter survival of rearing fish.
3. Establish guidelines for future research on the effects of canopy removal on temperature and ice conditions of small streams during winter months.
4. Since this year's data to determine if minnow traps are useful as a population estimator were inconclusive, it is recommended that this objective be continued.
5. Continue to collect aquatic insects to determine their distribution, abundance, and species diversity within certain types of rearing fish habitat and their relationships to rearing fish populations.

OBJECTIVES

1. To prepare an annotated bibliography on rearing fish.
2. To determine methods of making reliable population estimates of rearing fish.
3. To determine the distribution, abundance, and species diversity of aquatic insects within certain types of rearing fish habitat and the relationships to the rearing fish populations.

Location and Description of Study Site

A small stream in the Kadashan drainage (Chichagof Island, Lat. 57° 42' Long. 135°3', Quad Sitka C-4) was selected for this study (Fig. 1). The stream averaged about 6 feet wide with a length of approximately 1 mile accessible to fish. The stream is typical of many in southeast Alaska with deep pools, slow to moderate velocity, extensive undercut banks and overhanging vegetation, and with heavy organic deposits. The stream is dominated by populations of rearing anadromous Dolly Varden and coho salmon. There are also small numbers of rearing cutthroat (*Salmo clarki*) and steelhead (*Salmo gairdneri*) present.

TECHNIQUES USED

The study stream was surveyed and marked into sections 50 feet in length. For each population estimate a 50-foot section was blocked off at the upper and lower ends with fine mesh nylon seine nets to keep fish from entering or leaving the section. Ten double-ended conical minnow traps (Blackett, 1968, p. 73) baited with fresh salmon eggs were placed at evenly spaced distances in the section.

The traps were allowed to fish for one to two hours, then removed. The fish were removed from the traps, anesthesized with M.S. 222, counted, measured, and then marked with either fluorescent pigment or by fin clips.

When using granular fluorescent pigment, the material was sprayed from a conventional paint spray gun attached to a scuba tank air source. Fish were placed in a wire mesh basket and sprayed thoroughly at 80 p.s.i., holding the nozzle approximately one foot away.

During the latter part of the season, fin clips were used instead of fluorescent pigment. Fish were given a temporary mark by removing the tip of the upper or lower caudal lobe.

Once the marked fish had recovered from the effects of the anesthetic, they were immediately released in the enclosed section and allowed to distribute themselves as much as possible. Distribution usually occurred within about 10 minutes.

The enclosed section was then shocked with a backpack electrofishing unit until no more fish could be captured. It was assumed that if no more fish could be captured, then a close approximation of the actual rearing populations had been obtained.

Fish were then examined for fin clips or scanned with a portable ultraviolet light to detect fluorescent pigment marks and marked-unmarked ratios were obtained.

Population estimates were derived from marked/unmarked ratios by using Chapman's modification of the Peterson formula (Ricker, 1958):

$$N = \frac{(M+1)\ (C+1)}{R+1}$$

N = Population estimate
M = Number of fish marked
C = Number of fish in recapture sample
R = Number of marked fish in recapture sample (C)

Estimates were tested for bias by using the following methods described by Robson and Reiger (1964): $M+C \geqq N$ or $MC>4N$. These conditions were met by all the estimates conducted and thus are considered to be unbiased.

The ability of minnow traps to provide a population index was determined with the above methods. The initial trap catch was then statistically compared to the population estimates using the Chi-square method of Snedecor and Irwin as described in Snedecor (1962).

To evaluate the minnow trap as a population estimator, traps were used to catch the initial fish for marking which were then released and allowed to distribute themselves. Minnow traps were used as a recovery device to obtain fish for a marked/unmarked ratio. The section was then shocked until no more fish were collected to evaluate the methods' accuracy.

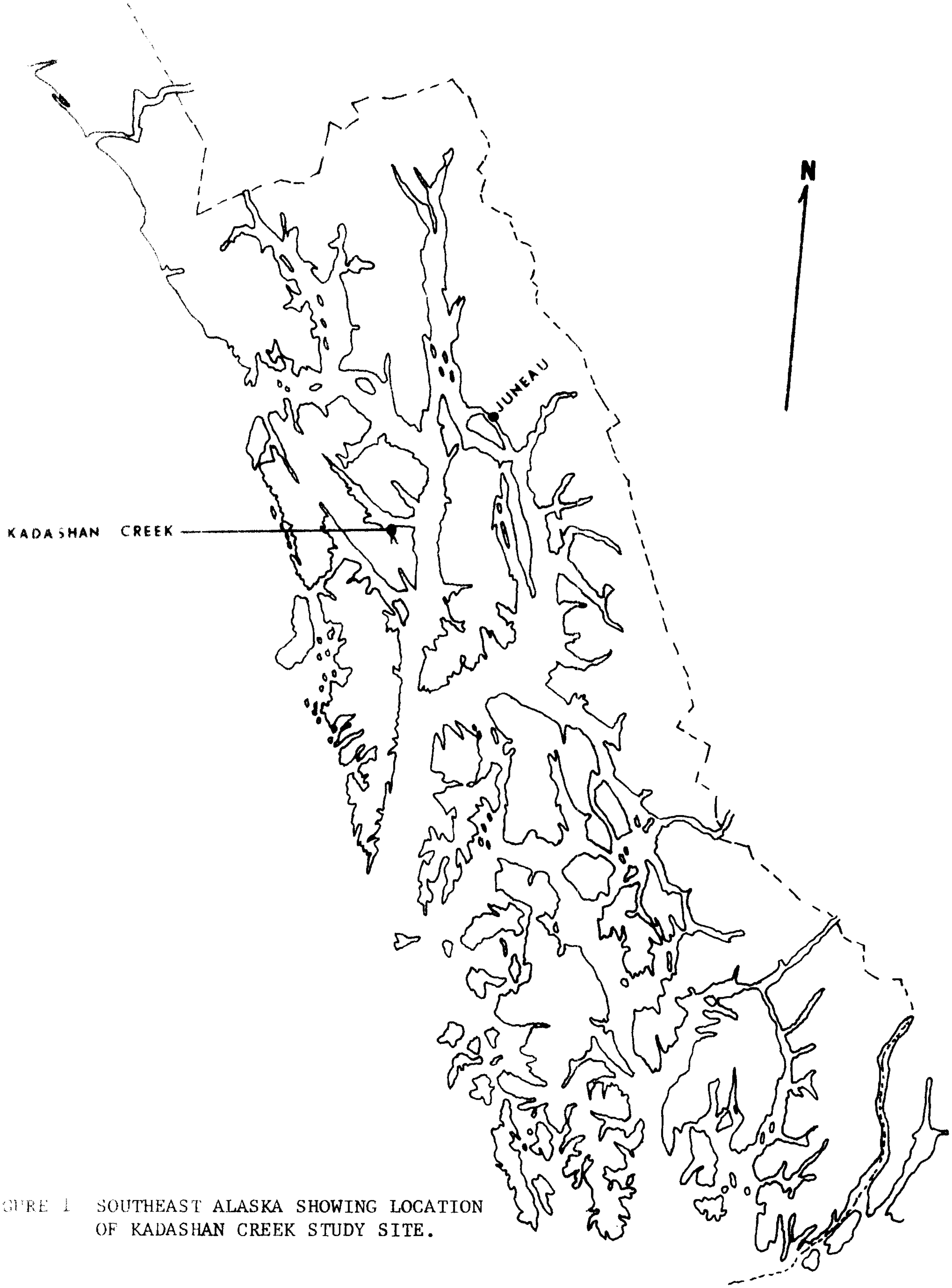

FIGURE 1 SOUTHEAST ALASKA SHOWING LOCATION OF KADASHAN CREEK STUDY SITE.

The shocker was evaluated by comparing the total catch (shocking until no more fish were captured) to the estimate for that respective section. These values were statistically compared using the t-test for the difference between the means.

The species composition of fish captured in traps was compared to the species composition derived from the estimated population and analyzed by Chi-square and t-tests.

To determine if minnow traps were size selective, the length frequencies of fish captured by minnow traps were statistically compared (using Chi-square "goodness of fit") to the length frequencies of the total population of fish captured by electrofishing.

Aquatic insects were collected by surbur sampler and aerial net. Specimens were preserved and taken to the highest taxonomic level possible. Data on the collections were compiled and a provisional list of aquatic insects in southeast Alaska was assembled.

FINDINGS

Trap Selectivity

Analysis of length frequencies of rearing Dolly Varden (Salvelinus malma) and coho salmon (Oncorhynchus kisutch) caught by trap and by the electrofishing method showed that traps do not capture a representative sample of the different size groups in the rearing community, and are size selective (Figs. 2 & 3). Statistical analysis (Table 1) showed that the length frequency distributions of fish obtained from minnow traps and electrofishing gear are equal for Dolly Varden over the length interval 61-150 mm, and for coho over the length interval 41-100 mm. The major disparity between trap and shocker catches occurred in fish measuring less than 41 and 61 mm for coho and Dolly Varden, respectively. Observations indicate that small coho are capable of escaping through the screen mesh of the traps but it is also possible that young fish avoid the traps because of the presence of larger fish.

To give continuity to estimates made from fish collected over a wide variety of habitats, occupied by varying proportions of fish under and over the minnow trap catchable size estimate, were conducted only on fish that ranged, 61 - 150 mm (Dolly Varden), and 41-100 mm (coho) in size.

Evaluation of Electrofishing Techniques

Using the assumption that electrofishing equipment could capture all the fish in an enclosed 50' section, each test section was shocked repeatedly until no more fish were captured. The number of passes through the section varied from 2 to 5, depending upon the density of fish and the amount of cover available that fish could escape to.

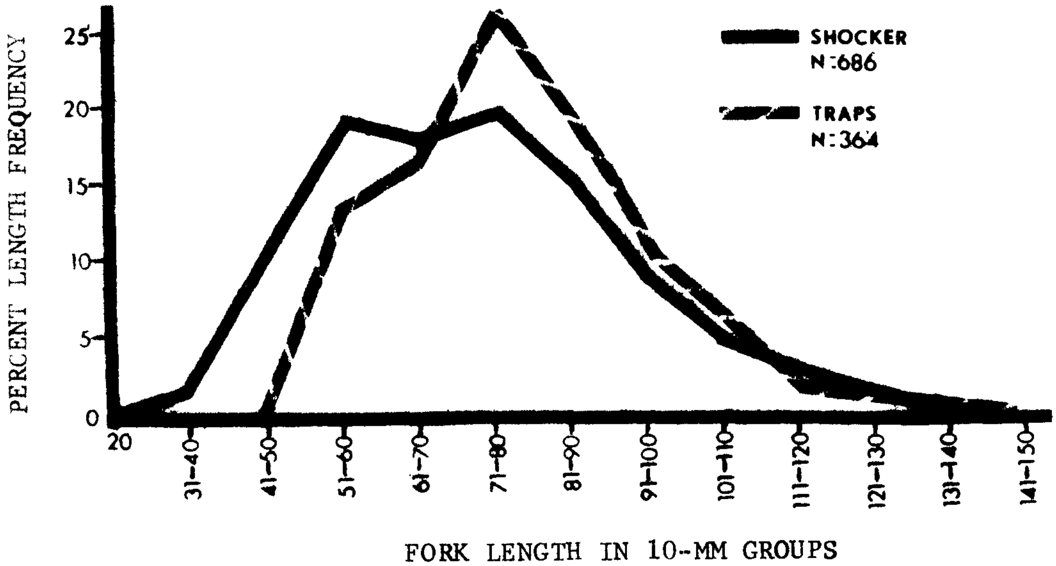

FIGURE 2 LENGTH FREQUENCY OF REARING DOLLY VARDEN CAPTURED IN MINNOW TRAPS AND BY ELECTROFISHING

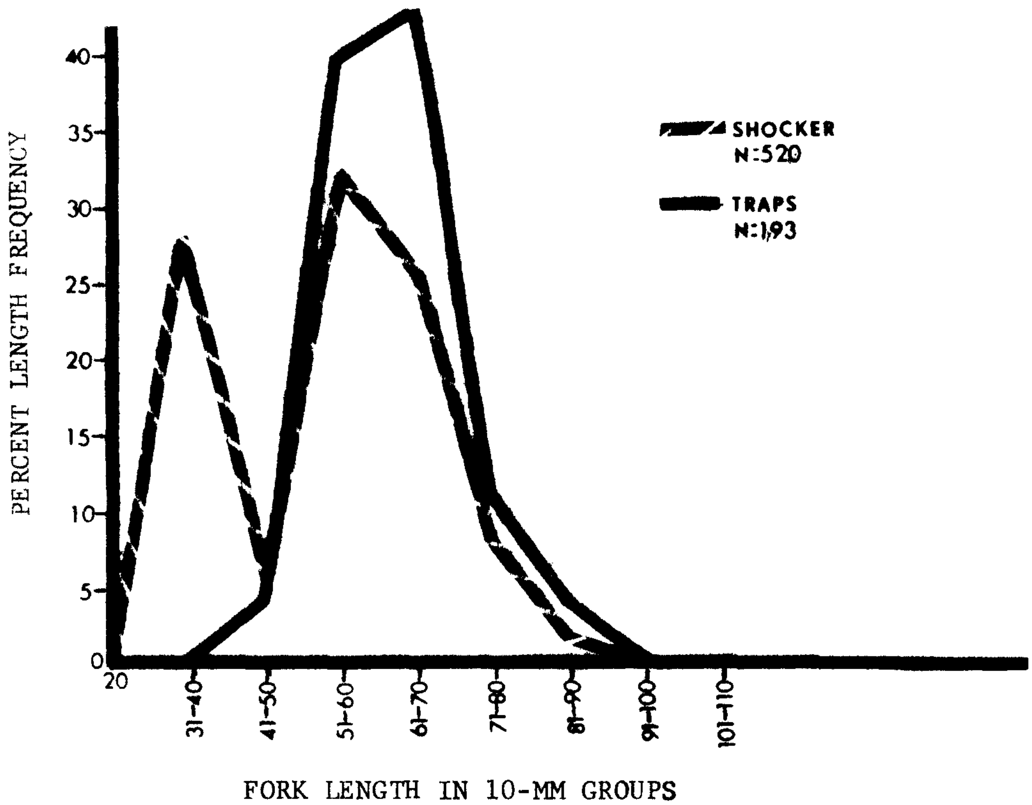

FIGURE 3 LENGTH FREQUENCY OF REARING COHO CAPTURED IN MINNOW TRAPS AND BY ELECTROFISHING

Table 1. Length Frequencies of Fish Captured by Minnow Trap and Electrofishing Gear and Summary of Goodness of Fit Calculation.

Length (mm)	Dolly Varden		Coho	
	Trap	Electrofish	Trap	Electrofish
31- 40	0	14	0	145
41- 50	0	80	8	30
51- 60	52	127	74	162
61- 70	61	121	82	132
71- 80	100	135	21	39
81- 90	72	107	7	10
91-100	38	50	1	2
101-110	23	29	-	-
111-120	9	9	-	-
121-130	4	6	-	-
131-140	4	7	-	-
141-150	1	1	-	-
Total	364	686	193	520

Summary of Goodness of Fit Calculation

Species	Length Interval	Degree of Freedom	Calculated Chi-square	Critical Value (5% Level)
Coho	31-100	6	86.06	12.59
	41-100	5	8.71	11.07
Dolly Varden	31-150	11	80.62	19.68
	51-150	9	22.15	16.92
	61-150	8	9.06	15.51

Table 2. Statistical Comparison of Total Shocker Catches and Calculated Peterson Estimates, Showing the Percent Difference.

Dolly Varden (N = 11)			Coho (N = 10)		
Pop. Est.	Catch	% Diff.	Pop. Est.	Catch	% Diff.
103	81	27.16	49	44	11.36
58	54	7.41	22	20	10.00
37	36	2.78	36	35	2.86
35	33	6.06	6	5	20.00
45	41	9.76	25	23	8.70
17	16	6.25	17	16	6.25
12	11	9.09	18	17	5.88
17	16	6.25	9	8	12.50
12	11	9.09	18	17	5.88
38	35	8.57	37	36	2.78
44	42	4.76	-	-	-

Max % Diff = 27.16 Max. % Diff = 20.00

Min. % Diff = 2.78 Min. % Diff = 2.78

Mean % Diff = 11.17 Mean % Diff = 7.23

The total number of fish captured by electrofishing equipment in each section was compared statistically to the Peterson estimate for that section.

The number of fish collected with the shocker closely approximated the calculated Peterson estimate for each test section (Table 2). The mean difference between the shocker catches and the Peterson estimates was determined to be 11.17% for Dolly Varden and 7.23% for coho.

The slope in the regression lines (Figs. 4 and 5) show that almost a 1-to-1 ratio exists between the shocker catches and the Peterson estimates and that a good correlation (r^2) exists.

There is no known method whereby every fish can be removed from a stream section with absolute certainty. Consequently, we are uncertain as to which method, repetitive shocking or Peterson estimates, are the most accurate means of determining rearing fish populations. However, we do know that both methods yield similar results and that an approximation of the numbers of fish living in a stream section can be obtained without conducting a Peterson marked/recapture estimate.

Minnow Trap Method as a Population Index

It was felt that minnow traps might be useful in making population indexes of rearing fish in small streams. If the minnow trap catch is density dependent then they may be able to capture a consistent percentage of rearing Dolly Varden and coho in each enclosed section. The use of minnow traps as a population indicator of rearing fish populations would enable one to quickly assess the quantity of rearing fish in a section of stream without making a formal population estimate.

There was considerable variation in the percentage of the estimated Dolly Varden and coho populations captured by minnow traps (Figs. 6 & 7). Trap catches were statistically compared to the population estimates in the test sections and Chi-square (5% level significance) showed that the trap catches were not consistently proportionate to the estimated populations of Dolly Varden and coho. Therefore we feel that minnow trap catches do not provide a reliable index of rearing Dolly Varden and coho populations and that catches may be governed by factors other than population density.

Minnow Trap Method as a Population Estimator

Only two replications were conducted to determine whether minnow traps could be utilized to estimate rearing fish populations. As a result, the data was inconclusive and the objective could not be fulfilled.

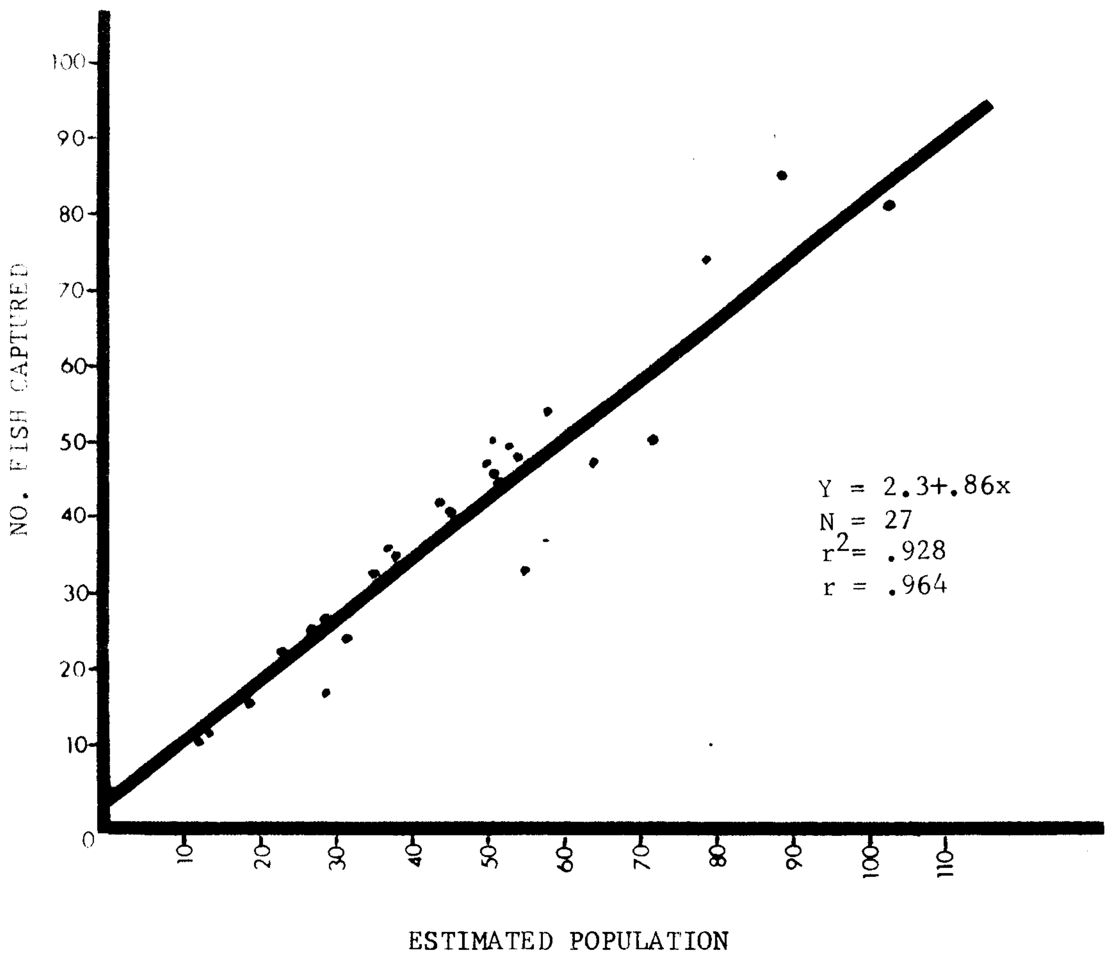

FIGURE 4 RELATIONSHIP OF ESTIMATED DOLLY VARDEN POPULATION TO THE TOTAL NUMBER OF DOLLY VARDEN CAPTURED

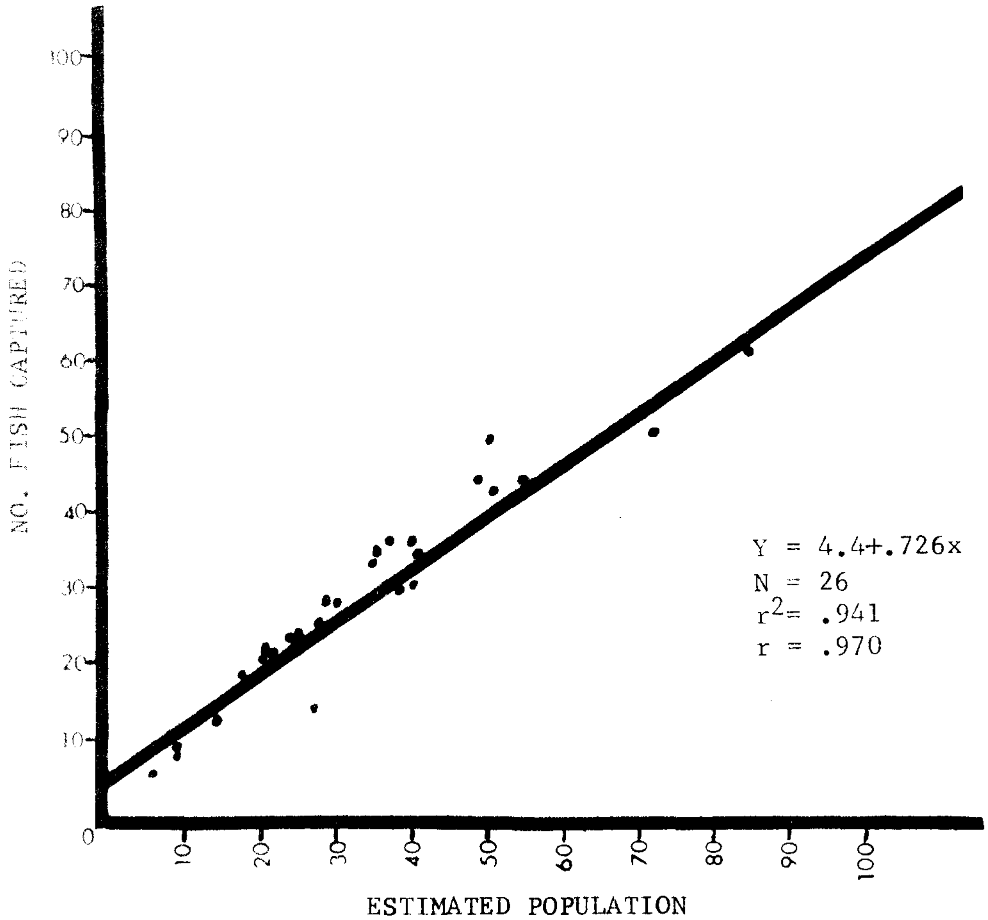

FIGURE 5 RELATIONSHIP OF ESTIMATED COHO POPULATION TO TOTAL NUMBER OF COHO CAPTURED

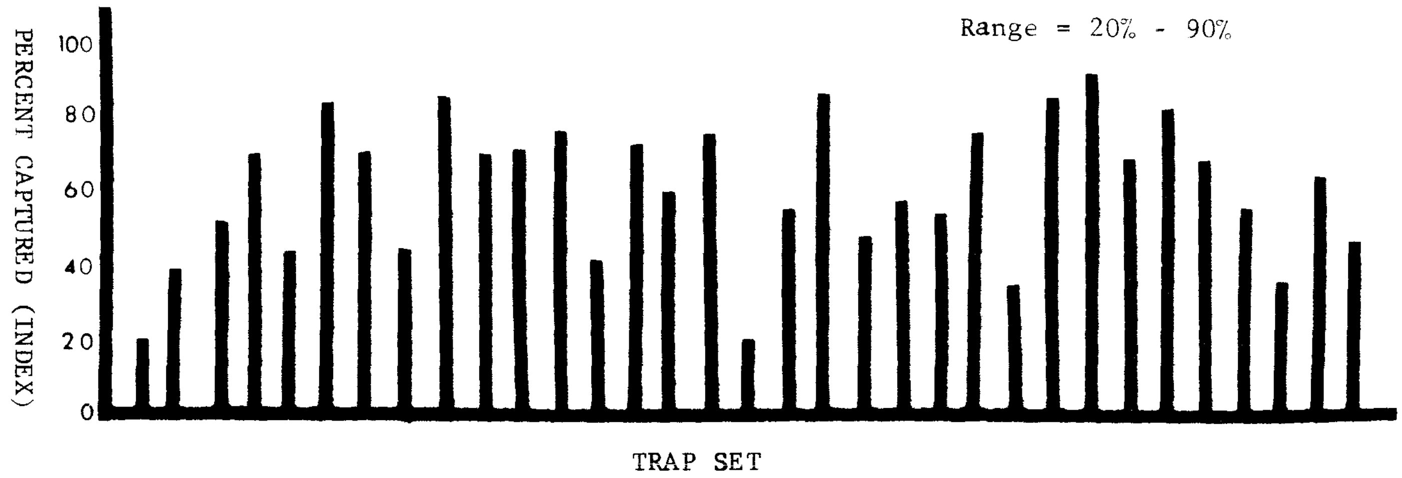

FIGURE 6 PERCENTAGE (INDEX) OF ESTIMATED DOLLY VARDEN POPULATION CAPTURED BY MINNOW TRAPS IN 33 TRAP SETS

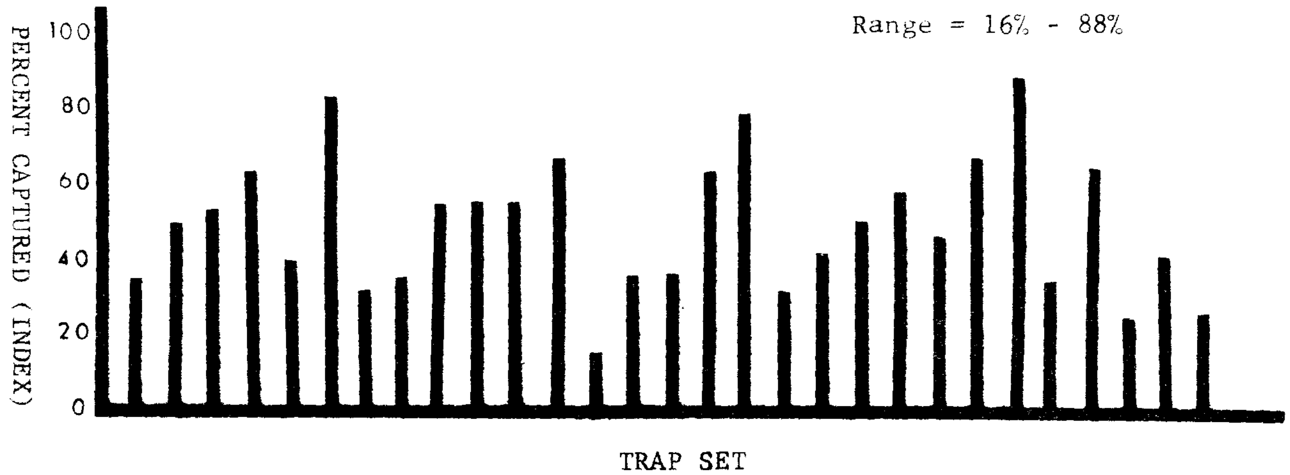

FIGURE 7 PERCENTAGE (INDEX) OF ESTIMATED COHO POPULATION CAPTURED BY MINNOW TRAPS IN 29 TRAP SETS

Evaluation of Species Composition Obtained by Minnow Traps

Field observations indicated the possibility that minnow trap catches may be able to reflect the species composition of the rearing community, as the percentage of Dolly Varden and coho captured in traps appeared to be similar to the composition of young char and coho in the estimated populations. T-tests showed that the percent species composition of the rearing fish captured in minnow traps was similar to the percent composition of Dolly Varden and coho in the estimated population (Table 3).

The mean difference between the minnow trap species composition and the estimated population composition was -4.22% with a range of 0% - 23% difference.

COMMENTS

The minnow trap, because of its field mobility, has become increasingly popular with various fisheries agencies in southeast Alaska for evaluating small rearing fish streams. Often, recommendations concerning logging and other land use activities are based on minnow trap results.

Since minnow trap catches vary considerably and do not catch a consistent portion of rearing Dolly Varden and coho populations, they should not be used as a tool to quantitatively assess a population for recommendation purposes.

Electrofishing methods for estimating populations appear to be promising. But many streams in southeast Alaska are filled with physical obstructions, such as logs, brush, and exposed root systems. Other have been filled with debris from logging activity making it almost impossible to use a shocker. Under these conditions minnow traps have been extensively used. But where critical analysis is required for recommendation purposes, some other methods should be adopted or used as a supplement.

The fluorescent pigment marking technique was found to be unsuitable for this job's needs. The technique requires a considerable amount of equipment that lacks the mobility for general field use. The technique is best suited for marking large volumes of fish and was impractical for the small numbers encountered at the study site.

Table 3. Species Composition of Dolly Varden and Coho in the Estimated Population and in Minnow Trap Catches (N = 27).

% Species Composition in Estimated Population		% Species Composition in Minnow Trap Catches		Diff. ± Between Est. Pop.& Trap Comp.
Dolly Varden	Coho	Dolly Varden	Coho	
87	13	81	19	6
66	34	60	40	6
67	33	67	33	0
72	28	74	36	- 2
51	49	53	47	- 2
85	15	85	15	0
50	40	66	34	-16
64	36	79	21	-15
40	60	47	53	- 7
55	45	61	39	- 6
67	33	68	32	- 1
54	46	56	44	- 2
61	39	66	34	- 5
56	44	66	34	-10
40	60	63	37	-23
47	53	40	60	7
62	38	54	46	8
75	25	85	15	-10
63	37	75	25	-12
61	39	52	48	9
57	43	66	34	- 9

Table 3. Species Composition of Dolly Varden and Coho in the Estimated Population and in Minnow Trap Catches (N = 27) (continued).

	% Species Composition in Estimated Population		% Species Composition in Minnow Trap Catches		Diff. ± Between Est. Pop. & Trap Comp.
	Dolly Varden	Coho	Dolly Varden	Coho	
	48	52	64	36	-16
	61	39	60	40	1
	58	42	56	44	2
	38	62	53	47	-15
	51	49	46	54	5
	43	57	50	50	- 7
Totals	63%	37%	64%	36%	- 1

Range: Dolly Varden -23 to +9% Difference

Coho - 9 to 23% Difference

Mean Difference: Dolly Varden = -4.22%

Coho = +4.22%

Standard Deviation of Differences = 8.55

Aquatic Insect Surveys

The following survey reports present information on aquatic insects from each stream examined from 1969 to summer of 1972.

All the surveys were qualitative in nature, as quantitative sampling requires intensive and lengthy sampling programs to approach accurate numerical values for each insect species. The number of samples usually varied between one and ten for all the systems, except for Hood Bay Creek where 83 samples were taken.

Collection data is presented in an abbreviated, simplified form. For complete understanding of the classification scheme of the specimens collected, refer to Table 4.

The Nakina River, in British Columbia, is included in the survey lists. It is felt that even though the river does not flow through Alaskan territory, it is part of the Taku River system, and many aquatic insects found in the Nakina are also common to the lower reaches of the Taku. Thus survey results from the Nakina and Taku (listed under glacial systems) should be examined together.

Corner Bay Creek (6/9/72)
57°44'20"N, 135°07'30"W; Quad. Sitka C-4

Ephemeroptera
- Baetis sp.
- Cinygmula sp.
- Epeorus sp.

Plecoptera
- Nemoura oregonensis Clsn.
- Leuctra sara Clsn.
- Alloperla revelstoki Jewett
- Alloperla oregonensis Frison

Trichoptera
- Limnephilidae

Diptera
- Tipulidae
- Chironomidae
- Simuliidae

Dog Salmon Creek (8/18/71)
55°20'55"N, 132°30'05"W; Quad. Craig B-2

Ephemeroptera
- Baetis tricaudatus Dodds
- Cinygmula sp.
- Ephemerella tibialis McD.

Plecoptera
- Leuctra augusta Banks
- Alloperla pallidula Banks
- Alloperla sp.

Diptera
- Polypedilum sp.

Fick Cove (6/25/71)
57°38'N, 135°40'W; Quad. Sitka C-6

Ephemeroptera
- Baetis bicaudatus Dodds
- Centroptilium prob. conturbatum McD.
- Epeorus sp.

Plecoptera
- Alloperla exquisita Frison
- Alloperla diversa Frison

Fish Bay Creek (8/7/71)
57°21'30"N, 135°29'00"W; Quad. Sitka B-5

Ephemeroptera
- Ameletus sparsatus? McD.
- Baetis bicaudatus Dodds

Cinygmula sp.
Epeorus (longimanus group) Eaton
Plecoptera
Nemoura cinctipes Banks
Nemoura frigida Clsn.
Alloperla exquisita Frison
Alloperla oregonensis Frison
Alloperla sp.

Glacial River Systems (No specific survey dates)

Since little is known about the insect fauna of glacial rivers in southeast Alaska, the following is a combined list from several systems.

Ephemeroptera
Baetis bicaudatus Dodds (glacial stream, Haines area)
Cinygmula sp. (Taku River)
Epeorus albertae (McD.) (Taku River)
Ephemerella prob. coloradensis Dodds (Taku River)
Plecoptera
Capnia excavata Clsn. (Mendenhall River, Juneau area)
Capnia nana Clsn. (Herbert River, Juneau area)
Isogenus frontalis colubrinus Hagen (Taku River)
Alloperla forcipata Neave (Eagle River, Juneau area; Taku River)
Trichoptera
Limnephilidae (Mendenhall River, Juneau Area)
Diptera
Tipulidae (Herbert River, Mendenhall River, Juneau area; Taku River)
Chironomidae
Heterotrissolcladius? sp. (Mendenhall River and Lake, Juneau area)

Gold Creek (Near Juneau, no specific survey date)
58°18'N, 134°25'W; Quad. Juneau B-2

Ephemeroptera
Ameletus sparsatus McD.
Baetis bicaudatus Dodds
Cinygmula sp.
Plecoptera
Nemoura oregonensis Clsn.
Brachyptera occidentalis (Banks)
Arcynopteryx prob. signata Hagen
Trichoptera
Rhyacophila sp.
Hydropsychidae
Arctopsyche sp.
Diptera
Chironomidae
Orthocladiinae
Simuliidae
Prosimulium sp.

Herman Creek (7/14/71)
59°25'N, 136°06"W; Quad. Skagway B-3

- Ephemeroptera
  - *Cinygmula* sp.
  - *Ephemerella coloradensis* Dodds
- Trichoptera
  - *Rhyacophila* sp.
  - *Arctopsyche* sp.
- Diptera
  - *Diamesa* sp.

Hood Bay Creek (Summer 1969)
57°26'N, 134°33'W; Quad. Sitka B-2

- Ephemeroptera
  - *Ameletus sparsatus*? McD.
  - *Baetis bicaudatus*? Dodds
  - *Baetis tricaudatus* Dodds
  - *Cinygmula* (par group)
  - *Epeorus* (*Iron*) (*longimanus* group)? Eaton
  - *Rithrogena* sp.
  - *Paraleptophlebia* sp.
  - *Ephemerella coloradensis* Dodds
  - *Ephemerella grandis flavitincta* McD.
  - *Ephemerella tibialis* McD.
- Plecoptera
  - *Nemoura* sp.
  - *Leuctra* sp.
  - *Capnia* sp.
  - *Isogenus nonus* Need. and Clsn.
  - *Alloperla* sp.
- Coleoptera
  - Dytiscidae
    - *Hydroporus* sp.
- Trichoptera
  - *Rhyacophila* sp.
  - *Limnephilus* spp.
- Diptera
  - Tipulidae
    - *Dicranota* sp.
    - *Hexatoma* sp.
  - Ceratopogonidae
    - *Palpomyia* sp.
  - Chironomidae
    - *Psectrotanypus* sp.
    - *Zavrelimyia* sp.
    - *Diamesa* sp.
    - *Pseudodiomesa* c.f. *arctica*
    - *Brillia* sp.
    - *Heterotrissocladius* sp.

Orthocladius sp.
Paraphaenocladius sp.
Chironomus sp.
Polypedilum sp.
Micropsectra sp.
Simuliidae
Prosimulium sp.
Rhagionidae
Atherix sp.

King Salmon River (8/28/72)
58°02'30"N, 134°20'30"W; Quad. Juneau A-2

Ephemeroptera
Ameletus sparsatus McD.
Baetis bicaudatus Dodds
Cinygmula sp.
Epeorus albertae Dodds
Plecoptera
Alloperla oregonensis Frison
Trichoptera
Rhyacophila sp.
Limnephilidae
Diptera
Tipulidae
Chironomidae
Tanypodinae
Orthocladiinae

Kook Lake and Inlet Streams (6/8/72)
57°40'N, 134°59'W; Sitka C-3, C-4

Ephemeroptera
Baetis bicaudatus Dodds
Cinygmula sp.
Rithrogena sp.
Ephemerella doddsi Need.
Plecoptera
Nemoura decepta Frison
Leuctra forcipata? ♀ Frison
Leuctra occidentalis Banks
Capnia excavata Clsn.
Kathroperla perdita Banks
Alloperla exquisita Frison
Alloperla revelstoki Jewett
Trichoptera
Rhyacophila sp.
Limnephilidae
Diptera
Chironomidae
Simuliidae

Nakina River (British Columbia (8/8/72)
59°N, 133°W

Ephemeroptera
  Baetis bicaudatus Dodds
  Cinygmula sp.
  Epeorus albertae (McD.)
  Ephemerella prob. *coloradensis* Dodds
Plecoptera
  Alloperla forcipata Neave
Trichoptera
  Rhyacophila sp.
  Limnephilidae
  Brachycentridae
    Brachycentrus sp.
Diptera
  Tipulidae
  Blephariceridae
  Deuterophlebiidae
    Deuterophlebia sp.
  Chironomidae
    Orthocladiinae
  Simuliidae
    Simulium sp.

Pats Creek, Wrangell (8/5/71)
56°20'30"N, 132°20'20"W; Quad. Petersburg B-2

Ephemeroptera
  Baetis tricaudatus Dodds
  Baetis sp.
  Cinygmula sp.
  Epeorus sp.
Plecoptera
  Leuctra augusta Banks
Trichoptera
  Limnephilidae
Diptera
  Chironomidae
  Simuliidae

[illegible] Harbor Creek (8/17/71)
[illegible] 25"N, 132°35'15"W; Quad. Craig D-2

Ephemeroptera
  Ameletus sparsatus? McD.
  Paraleplophlebia sp.
  Ephemerella grandis flavitincta McD.
Trichoptera
  Cheumatopsyche sp.?

Diptera
Tipulidae
Chironomidae
Cricotopus sp.?
Tanytarsus sp.
Rhagionidae
Atherix sp.

Rodman Creek (6/22/71)
57°26'00"N, 135°23'45"W; Quad. Sitka B-5

Ephemeroptera
Baetis bicaudatus Dodds
Cinygmula minus? Eaton
Cinygmula sp.
Epeorus (*Iron*) (*longimanus* group) Eaton
Plecoptera
Isogenus sp.
Alloperla revelstoki Jewett
Alloperla (*Alloperla*) sp.
Diptera
Tipulidae
Chironomidae
Diamesa sp.

Saginaw Creek (8/2/71)
56°50'30"N, 134°09'10"W; Quad. Port Alexander D-1

Ephemeroptera
Baetis bicaudatus Dodds
Cinygmula sp.
Epeorus sp.
Ephemerella coloradensis Dodds
Plecoptera
Alloperla pallidula Banks
Trichoptera
Rhyacophila sp.
Psychomyiidae
Psychomyia sp.?
Diptera
Chironomidae
Orthocladiinae

Seal Bay Creek (7/23/71)
57°50'30"N, 135°31'00"W; Quad. Sitka D-5

Ephemeroptera
Baetis bicaudatus Dodds
Baetis tricaudatus Dodds
Leptophlebiidae
Cinygmula sp.

Plecoptera
  Nemoura cinctipes Banks
  Nemoura decepta Frison
  Alloperla revelstoki Jewett
Trichoptera
  Limnephilidae
Diptera
  Tipulidae
    Dicranota sp.
  Chironomidae
    Heterotrissocladius? sp.

Sheep Creek (near Juneau, no specific survey date)
58°16'15"N, 134°19'15"W; Quad. Juneau B-2

Ephemeroptera
  Ameletus prob. sparsatus McD.
  Baetis bicaudatus Dodds
  Cinygmula sp.
  Rithrogena c.f. hageni
  Ephemerella doddsi Need.
Plecoptera
  Nemoura oregonensis Claassen
  Leuctra occidentalis Banks
  Kathroperla perdita Banks
  Alloperla pallidula Banks
  Arcynopteryx sp.
Trichoptera
  Rhyacophila sp.
  Limnephilidae
    Caborius? sp.
Diptera
  Tipulidae
    Dicranota sp.
  Ceratopogonidae
    Polpomyia sp.?
  Chironomidae
    Orthocladiinae 3 spp.

St. John Bay (7/28/71)
56°27'00"N, 132°57'30"W; Quad. Petersburg B-3

Ephemeroptera
  Baetis bicaudatus Dodds
  Cinygmula sp.
  Ephemerella (Drunella) sp.
Plecoptera
  Leuctra augusta Banks
  Alloperla pallidula Banks

Diptera
  Chironomidae
    Polypedilum sp.
  Simuliidae
    Simulium

Switzer Creek (No specific survey date)
58°21'45"N, 134°30'10"W; Quad. Juneau B-2

Ephemeroptera
  Baetis bicaudatus Dodds
  Cinygmula sp.
  Ephemerella doddsi Needham
  Ephemerella coloradensis Need.
Plecoptera
  Nemoura cinctipes Banks
  Nemoura oregonensis Clsn.
  Capnia confusa Clsn
  Capnia melia Frison
  Brachyptera occidentalis (Banks)
Trichoptera
  Rhyacophila sp.
  Limnephilidae
Diptera
  Tipulidae
    Dicranota sp.
  Chironomidae
    Diamesa sp.
    Orthocladiinae

Unnamed Stream, Mile 28, Petersburg Road System (7/27/71)
56°35'N, 132°34'W; Quad. Petersburg C-2

Ephemeroptera
  Baetis bicaudatus Dodds
  Cinygmula sp.
  Epeorus albertae Eaton
  Epeorus (*Iron*) (*longimanus* group) Eaton
  Ephemerella coloradensis Dodds
Plecoptera
  Alloperla pallidula Banks
Diptera
  Tipulidae

108 Creek, Whale Pass (7/29/71)
56°8'N, 133°10'W; Quad. Petersburg A-4

Ephemeroptera
  Baetis sp.
  Cinygmula sp.
  Ephemerella coloradensis Dodds

Ephemerella doddsi Need.
Plecoptera
Nemoura sp.
Alloperla sp.
Trichoptera
Rhyacophila sp.
Limnephilus sp.
Diptera
Chironomidae
Simuliidae

Whiterock River (7/5/72)
57°32'45", 134°50'55"W; Quad. Sitka C-3

Ephemeroptera
Baetis sp.
Cinygmula sp.
Epeorus sp.
Plecoptera
Capnia excavata Clsn.
Alloperla exquisita Frison
Alloperla oregonensis Frison
Trichoptera
Rhyacophila sp.
Diptera
Chironomidae
Tanypodinae
Orthocladiinae

Whitewater Bay Creek (6/29/71)
57°15'N, 134°37'W; Quad. Sitka A-2

Ephemeroptera
Baetis bicaudatus Dodds
Cinygmula sp.
Epeorus (Iron) (longimanus group) Eaton
Ephemerella grandis flavitincta Need.
Plecoptera
Capnia sp.
Alloperla exquisita Frison
Trichoptera
Rhyacophila sp.
Diptera
Tipulidae
Dicranota sp.
Ceratopogonidae
Palpomyia sp.
Chironomidae
Orthocladius sp.
Heterotrissocladuis sp.
Polypedilum sp.
Micropsectra sp.

Wilson Creek, Petersburg Road System (7/27/71)
56°34"N, 132°39'W; Quad. Petersburg C-2

Ephemeroptera
- *Baetis bicaudatus* Dodds
- *Cinygmula* sp.
- *Epeorus* (*Iron*) (*longimanus* group) Eaton

Diptera
- Rhagionidae
  - *Atherix* sp.

Young Bay Creek, Admiralty Cove (11/2/72)
58°10'N, 134°40'W; Quad. Juneau A-2

Ephemeroptera
- *Ameletus* prob. *sparsatus* McD.
- *Baetis bicaudatus* Dodds
- *Cinygmula* sp.
- *Epeorus* (*Iron*) *longimanus* Eaton
- *Epeorus* (*Ironopsis*) *grandis* McD.
- *Rithrogena robusta*? Dodds
- *Ephemerella doddsi* Need.

Plecoptera
- *Nemoura* sp.
- *Capnia* sp.
- *Isogenus* sp.
- *Alloperla* spp.

Coleoptera
- Amphzoidae
  - *Amphizoa* sp.

Trichoptera
- *Rhyacophila* 2spp.
- Psychomyiidae?
- Hydropsychidae
  - *Arctopsyche* sp.
- Limnephilidae
  - *Dicosmeocus*? sp.
  - *Pycnopsyche*? sp.

Diptera
- Chironomidae
  - *Orthocladius* sp.
- Simuliidae
  - *Prosimulium* sp.

Provisional List of Aquatic Insects

The following list compiles information on aquatic insect populations gathered from observations and collections from 29 stream systems in southeast Alaska. (Table 4).

Almost all determinations, with the exception of the Plecoptera, have been made from the immature forms and are regarded as tentative until more information can be collected.

Determination of specimens belonging to the orders Trichoptera and Diptera requires a degree of expertise and training, which at this time is beyond the scope of this project for the purposes of general collecting. Consequently, determinations have only been made to the family level for many specimens in these groups.

A question mark following the name of an insect denotes doubtful placement.

The figures listed for each taxon is not intended to portray a group's abundance or distribution in southeast Alaska but merely notes the number of streams the individuals have been collected in.

Comments on Aquatic Insect Surveys

It was found that the number of samples conducted in a watershed determine to a large extent the completeness of each faunal list. Apparently a small number of samples yield only limited qualitative information, while large numbers of samples (Hood Bay Creek; 83 samples) yields more detailed information of the benthos. Many of the species collected at Hood Bay were represented by only a few specimens, such as: *Paraleptophlebia* sp., *Ephemerella tibialis* Mcd., *Isogenus nonus* Need & Clssn., *Zavrelimyia* sp., and *Prosimulium* sp. These species would not have been collected had it not been for the large number of samples, taken over a wide range of aquatic habitats.

The investigator will find it much easier to identify stomach contents of fish if he first becomes familiar with specimens collected from the benthos, as these specimens are usually in better condition. The investigator need not take excessive number of samples from the benthos in order to draw correlations between the benthos and stomach samples. It was found that fish tend to feed on the commonly represented species and rarer forms are seldom found in the stomach samples (Elliott and Armstrong, 1972). Thus a small number of samples will usually yield enough information to establish the identity of the common forms.

Analysis of insect surveys appears to show a general faunal pattern in S.E. Alaska streams. There are several species and genera which were common to almost all the streams surveyed. The collector can usually anticipate finding these organisms in any stream that is sampled. A preliminary list of these organisms

Table 4. Provisional List of Aquatic Insects in Southeast Alaska.

	No. of Streams Known to Occur in (29 streams sampled)
Order EPHEMEROPTERA	
Family SIPHLONURIDAE	
Genus Ameletus	
sparsatus McDunnough 1931	8
Family BAETIDAE	
Genus Baetis	
bicaudatus Dodds 1923	20
tricaudatus Dodds 1923	4
Genus Centroptilium	
conturbatum? McDunnough 1929	1
Family HEPTAGENIIDAE	
Genus Cinygmula	
minus? (Eaton 1885)	1
Cinygmula sp.	24
Genus Epeorus	
Subgenus Iron	
albertae (McDunnough 1924)	4
longimanus (Eaton 1885)	7
Subgenus Ironopsis	
grandis (McDunnough 1924)	1
Epeorus sp.	5
Genus Rithrogena	
hageni? Eaton 1885	1
robusta Dodds 1923	1
Rithrogena sp.	2
Family LEPTOPHLEBIIDAE	
Genus Paraleptophlebia sp.	2
Family EPHEMERELLIDAE	
Genus Ephemerella	
Subgenus Drunella	
coloradensis Dodds 1923	8
doddsi Needham 1927	8
grandis flavitincta McDunnough	3
Subgenus Serratella	
tibialis McDunnough 1924	2
Order PLECOPTERA	
Family NEMOURIDAE	
Subfamily NEMOURINAE	
Genus Nemoura	
Subgenus Podmosta	
decepta Frison 1942	2
Subgenus Visoka	
cataractae Neave 1933	1

	No. of Streams Known to Occur in (29 streams sampled)
Subgenus Zapada	
cinctipes Banks 1897	4
frigida Claassen 1923	1
haysi Ricker 1952	1
oregonensis Claassen 1923	
Subfamily LEUCTRINAE	
Genus Leuctra	
Subgenus Despaxia	
augusta Banks 1907	6
Subgenus Paraleuctra	
forcipata Frison 1937	3
occidentalis Banks 1907	2
sara Claassen 1937	1
Subfamily CAPNIIDAE	
Genus Capnia	
confusa Claassen 1924	1
excavata Claassen 1924	5
melia Frison 1942	2
nana Claassen 1924	3
projecta Frison 1937	1
Subfamily TAENIOPTERYGINAE	
Genus Brachyptera	
Subgenus Doddsia	
occidentalis (Banks) 1900	2
Family PERLODIDAE	
Genus Arcynopteryx	
Subgenus Megarcys	
signata (Hagen) 1874	2
Genus Isogenus	
Subgenus Isogenoides	
frontalis colubrinus Hagen 1874	1
Subgenus Kogatus	
nonus (Needham and Claassen) 1925	1
Family CHLOROPERLIDAE	
Subfamily PARAPERLINAE	
Genus Kathroperla	
perdita Banks 1920	4
Subfamily CHLOROPERLINAE	
Genus Alloperla	
Subgenus Neaviperla	
forcipata Neave 1929	3
Subgenus Suwallia	
pallidula (Banks) 1904	6
Subgenus Sweltza	
coloradensis? (Banks) 1898	1
exquisita Frison 1935	
oregonensis Frison 1935	6
revelstoki Jewett 1955	4

	No. of Streams Known to Occur in (29 streams sampled)
Subgenus Triznaka	
diversa Frison 1935	2
Order COLEOPTERA	
Note: very few coleoptera have been found during surveys of creeks and rivers in southeast Alaska. Most of them are confined to lentic environments, sloughs, and slow moving rivers.	
Order TRICHOPTERA	
Family RHYACOPHILIDAE	
Genus Rhyacophila	13
Family PSYCHOMYIIDAE	
Genus Psychomyia	2
Family HYDROPSYCHIDAE	
Genus Arctopsyche	2
Cheumatopsyche?	1
Family LIMNEPHILIDAE	8
Genus Dicosmoecus	2
Limnephilus	1
Caborius?	1
Pycnopsyche?	1
Family BRACHYCENTRIDAE	
Genus Brachycentrus	1
Order DIPTERA	
Family TIPULIDAE	9
Genus Dicranota	5
Hexatoma	1
Family BLEPHARICERIDAE	1
DEUTEROPHLEBIIDAE	
Genus Deuterophlebia	1
Family CERATOPOGONIDAE	
Genus Palpomyia	3
Family CHIRONOMIDAE	4
Subfamily TANYPODINAE	2
Genus Psectrotanypus	1
Zavrelimyia	1
Subfamily DIAMESINAE	
Genus Diamesa	4
Pseudodiamesa c.f. arctica	1
Subfamily ORTHOCLADIINAE	7
Genus Brillia	1
Heterotrissocladius	4
Orthocladius	3

	No. of Streams Known to Occur in (29 streams sampled)
Genus Cricotopus	1
Paraphaenocladius	1
Subfamily CHIRONOMINAE	
Genus Chironomus	1
Polypedilum	4
Micropsectra	2
Tanytarsus	1
Family SIMULILDAE	
Genus Simulium	2
Prosimulium	3
Family RHAGIONIDAE	
Genus Atherix	3

has been drawn up (Table 5).

Table 5. A List of the Most Commonly Occurring Aquatic Insects in Southeast Alaska.
[non-glacial streams]

EPHEMEROPTERA
- SIPHLONURIDAE
  - *Ameletus sparsatus* Med.
- BAETIDAE
  - *Baetis bicaudatus* Dodds
- HEPTAGENIIDAE
  - *Cinygmula* sp.
  - *Epeorus* sp.
  - *Rithrogena* sp.
- EPHEMERELLIDAE
  - *Ephemerella coloradensis* Dodds
  - *Ephemerella doddsi* Needham 1927

PLECOPTERA
- NEMOURIDAE
  - *Nemoura* sp.
  - *Leuctra* sp.
  - *Capnia* sp.
- CHLOROPERLIDAE
  - *Alloperla* sp.

TRICHOPTERA
- RHYACOPHILIDAE
  - *Rhyacophila* sp.
- LIMNEPHILIDAE

DIPTERA
- TIPULIDAE
- CHIRONOMIDAE
- SIMULIIDAE

In most streams, there are several dominant species or genera in each order. In the order Ephemeroptera, Baetis bicaudatus-Cinygmula sp., associations are the most common. Often, Baetis bicaudatus-Epeorus sp. Rithrogena sp. can be found

The most common of the Plecoptera are the Nemouridae and Chloroperlidae (Alloperla sp.) groups. These associations can be found in almost all streams.

The most common member of the order Trichoptera is the family Limnephilidae. Usually two or more species can be found in a stream. The genus Rhyacophila (Rhyacophilidae) is also present in most streams. The family Chironimidae (Diptera) appears to be represented in all streams (though often not recorded). Observations and collections indicate that this family not only dominates the order but may be the most abundant in terms of both species and biomass in S.E. Alaskan streams.

ANNOTATED BIBLIOGRAPHY

The following annotated bibliography represents the background information on the ecology and behavior of rearing fish. It should be considered preliminary as only a portion of the available literature is presented.

For the purposes of this paper, the rearing portion of the life history was defined as that portion between emergence and smoltification in the anadromous forms and from emergence to sexual maturity in nonanadromous forms. The bibliography presents only those papers dealing with stream and river habitat and does not include references to lake environments.

Allee, Brian J.

1971. A study of the behavioral interactions between juvenile coho salmon and steelhead trout. Research in Fisheries, Fisheries Research Institute, Univ. Wash., Contrib. No. 340. p. 36.

"The data so far indicate that there are definite carrying capacities for any given habitat type. These are based on the space available and the food produced. Other variables such as velocity, depth, and cover tend to modify the carrying capacity as well. Preliminary data suggest that juvenile coho are more aggressive than steelhead in both pool and riffle habitat types. However, more juvenile coho are found in pools and more steelhead occur in riffles.

Similar experiments, testing the ability of hatchery-reared fish of both species against their wild counterparts, show that hatchery fish are found in a pool and riffle habitat at densities above that which the wild fish attain and thus, perhaps, above that which the available food can support. This may be considered as a disadvantage for hatchery fish and may, with further work, help to explain the low survival rate of planted fry and fingerlings in the wild environment.

These studies in natural and experimental streams may help to evaluate production estimates and determine if it would be advantageous to manage individual streams with certain characteristics for a particular species of fish."

Allen, K. Radway.

1941. Studies on the biology of the early stages of the salmon (Salmo salar) 2. Feeding habits. J. Anim. Ecol. 10(1):47-76.

"1. A study was made of the relation between the food of young salmon and the fauna, carried out between June 1935 and October 1938 on the river Eden and on some tributaries of the Thurso River.

2. The factors determining the composition of the food eaten by fish are considered theoretically, and it is shown that both the nature of the potential food animals and the behaviour of the fish have an effect.

3. The nature of a potential food animal affects is availability to the fish, and a method of measuring this is developed. Application of this method to all the principal types of animals in the fauna shows that the animals may be divided into four categories according to their availabilities.

4. The availability of an animal depends primarily upon its habits, being affected by its activity and by the degree of exposure of the habitat it usually occupies. The size of an animal and the presence or absence of a hard outer covering also appear to influence the extent to which it is available to fish of different sizes.

5. The behaviour of a fish determines the extent to which it selects its food. The degree of selection exercised by a fish increases as the number of animals in its stomach increases. At least 80% of fish with more than ten animals in their stomachs appear to be exercising selection.

6. Application of an arbitrary test showed that selection was confined to a few of the most numerous food animals. In the first-year fish, nearly all the selected animals belonged to the two most numerous groups, and in the second-year fish to the five most numerous groups. A few groups of animals were found to be very rarely selected, although fairly abundant in the available fauna.

7. The composition of the food of a population of fish is similar to the composition of the fauna available to it, except that selection tends to cause the animals most abundant in the available fauna to be eaten to a relatively greater extent.

8. The measurement of the availabilities of the different animals in the fauna by the methods used in this paper can be applied to the evaluation of faunas as food supplies for young salmon.

9. Examination of the quantity of food taken on the surface showed that more surface food is taken by second-year fish than by first-year fish, that more surface food is taken in the Thurso system than in the Eden system, and that surface feeding takes place to a much greater extent in the months August to October than at other times."

Allen, K. Radway.
1941. Studies on the biology of the early stages of the salmon (Salmo salar) 3. Growth in the Thurso River system, Caithness. J. Anim. Ecol. 10(2):273-295.

"1. A study of the growth of young salmon in three tributaries of the Thurso River, Caithness, was carried out between August 1937 and October 1938. These results are compared with those from a similar study of the young salmon of the river Eden, in Cumberland and Westmorland.

2. The seasonal variations in the growth-rate and related phenomena in the Thurso system correspond extremely closely with those from the Eden.

(a) Growth takes place during only a part of the year; the growth period, April to September, is slightly shorter in the Thurso system than in the Eden.

(b) Growth is slower in the later part of the summer than in the early part.

(c) The amount of food found in the stomachs of the salmon is at a maximum during the early part of the rapid growth period in both first and second years, and then falls steadily to a low value at which it remains during the winter.

(d) The seasonal changes in the condition factor of the fish may be correlated with changes in the rate of growth. When condition is good the rate of growth is high and when condition is poor the rate of growth declines or remains low.

3. Further evidence is produced in support of the hypothesis that the temperature 7° C. is critical in determining the activity and hence the feeding and growth of young salmon.

4. The mean rate of growth in the second year for the period June to August is calculated for the three Thurso tributaries and for the Eden, and from this a theoretical date of commencement of growth is obtained. This date is considerably later in all the Thurso tributaries than in the Eden, and the difference is similar in extent to the difference between the average dates of the rise of temperature to 7° C. in the two systems.

5. Division of the total annual increment by the June to August growth rate indicates that the total length of the growth period in both first and second years is less in the Thurso system than in the Eden.

6. The order of the streams studied is the same in respect to the rate of growth during the slow growth period, August to October, as to the rate of growth from June to August. The ratio between the rates of growth during these two periods shows that it is similar in the different waters in the first year but varies widely in the second year. In both years the rate of growth during the slow growth period is relatively higher in the Eden than in the Thurso tributaries.

7. While either the maximum summer temperatures or seasonal variations in the fauna may in some cases affect the extent of the decrease in the rate of growth in late summer neither is the primary cause.

8. The order of the streams is the same in regard to the relation between the food supply and the fish populations as in regard to the rate of growth during the rapid growth period.

9. The amount of growth in one year depends on:

(a) The amount of food available, which affects the rate of growth during the rapid growth period.

(b) The date of the rise of temperature to 7° C. which determines the date of commencement of rapid growth.

(c) The unknown factors which determine the length of, and the rate of growth during, the slow growth period.

10. Comparison between the second year increment and the date of the rise of temperature to 7° C., throughout the natural range of the salmon, shows that while this factor may affect the annual increment within restricted

areas, some other factor is of greater significance in determining its magnitude in different parts of the range."

Armstrong, Robert H.
1963. Investigations of Anadromous Dolly Varden populations in Lake Eva-Hanus Bay drainages, Southeastern Alaska. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1962-1963, Project F-5-R-4, 4(3-B): 78-122.

"Studies also conducted to gather information on food and feeding habits, age and growth, sex ratio, spawning requirements, fecundity and freshwater rearing requirements." Information on age and length frequency is included.

Armstrong, Robert H.
1967. Investigations of anadromous Dolly Varden populations in the Hood Bay drainages, Southeastern Alaska. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1966-1967, Project F-5-R-8, 8(2-B):33-56.

"Stomach analysis of inmigrant char indicated that salmon eggs were the most frequently eaten food while the char were in Hood Bay Creek. Insects of the orders Plecoptera and Diptera were the most frequently found food item in rearing char."

Armstrong, Robert H.
1970. Investigations of anadromous Dolly Varden populations in Hood Bay drainages, southeast Alaska. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1969-1970, Project F-9-2, 11(2-B):37-46.

"This report presents the results of the fifth year of study at Hood Bay and the eighth year of investigation on the life history of Dolly Varden, Salvelinus malma. Emphasis of study included a smolt transplant experiment from the North Arm streams to Hood Bay Creek, homing and straying of Dolly Varden at maturity, and habitat preferences and intra-stream movements of rearing Dolly Varden and coho salmon, Oncorhynchus kisutch, at Hood Bay Creek.

Population estimates of 52,737 Dolly Varden and 24,029 coho salmon were calculated for these species rearing in Hood Bay Creek. A similar rearing environment with a preference for sheltered pools, sloughs, and undercut banks was indicated for both rearing Dolly Varden and coho salmon. Dolly Varden were found to select most of their food from the stream bottom; coho salmon selected most of their food from the water surface."

Armstrong, R. H. and Paul D. Kissner.
1969. Investigations of anadromous Dolly Varden populations in Hood Bay drainages, Southeastern Alaska. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1968-1969, Project F-9-1, 10(2-B):45-92.

"Food studies of the rearing fish in Hood Bay Creek indicated that competition for food was occurring between Dolly Varden, coho and cottids. Competition for space between Dolly Varden and coho was also indicated. It was estimated that rearing Dolly Varden, coho and cottids consumed between 11 and 20 percent of the pink and chum salmon fry outmigrating the South Arm Stream in 1968."

Armstrong, Robert H. and W. M. Morton.
1969. Revised annotated bibliography on the Dolly Varden char. Alaska Department of Fish and Game. Research Rept. No. 7:108 pp.

"This revised bibliography contains 507 published and unpublished references on the Dolly Varden, Salvelinus malma (Walbaum)."

Armstrong, R. H. and R. D. Reed
1971. Dolly Varden Sport Fishery - Juneau Area. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1970-1971, Project F-9-3, 12(R-IV):26 pp.

"This report presents the results of the sixth year of study at Hood Bay and the ninth year of investigation on the life history of Dolly Varden, Salvelinus malma. Emphasis of study included behavior observations of Dolly Varden and coho salmon, Oncorhynchus kisutch, fry and fingerling; evaluation of the Dolly Varden smolt transplant conducted in 1969; an experiment to determine the role of sight and olfaction in homing Dolly Varden, and float tracking of mature Dolly Varden.

During observations in the natural environment and in an aquarium, coho fry frequently attacked Dolly Varden fry; no incidence of Dolly Varden fry aggression toward coho fry was recorded. As fingerling, Dolly Varden attacked coho on several occasions, with only one record of a coho attacking a Dolly Varden obtained.

Coho fry and fingerling sampled food more often at the surface than Dolly Varden fry and fingerling, which sampled food mostly at the stream bottom. Coho fingerling obtained food introduced into the aquarium more often than Dolly Varden fingerling.

Stomach content of Dolly Varden and coho fingerling sampled in Hood Bay Creek indicate coho fed more frequently on surface insects than did the Dolly Varden."

Au, D. W. K.
1971. Population dynamics of the coho salmon and its response to logging in three coastal streams. (Taken from summary of Ph.D Thesis) Oregon State University.

Immediately upon emergence, coho fry begin dispersal downstream moving up to 300 meters each night. This nocturnal movement continues until each is settled and take up residence. During the day the fry maintain position and feed in the current. Experiments and observations suggest that nocturnal migratory behavior is part of a developmental sequence beginning with the initial hydrostatic disequilibrium of the fry and ending in resting behavior at night. Until this stage is reached, the nocturnaly active fry are subject to displacement downstream. The transition to quiescent nocturnal behavior is gradual, taking up to a week for some individuals and may be determined by the initial condition of the fry, degree of competition, and food availability during the day. Intraspecific competition from prior resident fry delays the aquisition of nocturnal resting behavior and acts to augment dispersal.

Distribution evidently functions to move fish away from the redd sites into nursery areas of the stream. Evidence suggests that fry migration is inefficient as a mechanism of population regulation but does reduce stresses of overpopulation.

Coho territorial and agonistic behavior, while important in dispersal continues into the fall until populations are adusted to stable levels. These adjustments occur through mortality, not migration. Calculations indicate that 80% of each years recruitment die by September and that mortality rates are density dependent and thus regulatory in nature. Territorial and agonistic behavior are thought to be most important in this respect. Population levels change very little after September, thus producing the near constant smolt output each year. The ability of coho populations to deal with variable fry input each year apparently also extends to the detrimental effects of logging.

Growth among coho populations occurs in the summer and spring just prior to immigration as smolts. The average coho grows 45 mm from June to next April. A decrease in mean size in one area was associated with high stream temperatures in the unshaded stream and changes in population structure also occurred.

Biomass decreases with the populations in spring and early summer and increases after population stability has been achieved. It is often temporarily sustained the next spring by a balance between smolt outmigration and increased growth rate.

About 90% of the yearling coho immigrate as smolt, and the smolt yield is independent of initial year class strength in June, a consequence of population regulation via mortality.

Becker, D. C.

1969. Food and feeding of juvenile chinook salmon in the Columbia River at Hanford. Biological Effects of Thermal Discharges, Ann. Prog. Rept., Battelle Northwest, Richland, Wash. (Taken from Sinha 1971).

"Stomach contents of 445 young chinook salmon taken near Hanford were examined. They fed primarily upon aquatic insects, mainly chironomids, and secondarily on terrestrial insects. No evidence was found to suggest that heated effluents discharged in midwater plumes and which rapidly mix

with the colder river water adversely affects either insect production or feeding activity of fish. Food intake was restricted in a few shoreline areas receiving warm water via intragravel seepage. Thermal discharge to the river, when waters are below preferred levels during spring runoff, may actually benefit the fish."

Bjornn, T. C.
1971. Trout and salmon movements in two Idaho streams as related to temperature, food, stream flow, cover, and population density. Trans. Amer. Fish. Soc. 100(3):423-438.

"Many juvenile salmon and trout migrated from the Lemhi River drainage each fall-winter-spring period. Seaward migration of anadromous trout and salmon normally occurred in the spring but pre-smolt anadromous and non-anadromous fishes also left the stream usually beginning in the fall. I compared data on temperature, food abundance, stream flow, cover and population density with movements and conducted field and laboratory tests to determine reasons for the two types of movements.

Smolts of the anadromous species migrated for an obvious reason but none of the factors I examined appeared to "stimulate or release" their seaward migration. Movement frequently coincided with changes in water temperature and stream flow, but I could not establish a consistent casual relationship and concluded that photoperiod and perhaps growth must initiate the physiological and behavioral changes associated with seaward migration.

Non-anadromous and pre-smolt anadromous species emigrated from the streams for different reasons than the smolts. I postulated that fish found the stream environment unsuitable during the winter. Stream temperature declined in the fall as fish began moving from the streams but I could not induce more fish to stay in test troughs with 12 °C water versus troughs with 0-10 °C water. Fish emigrated before abundance of drift insects declined in winter. Emigration occurred in spite of the relatively stable flows in both streams. Population density modified the basic migration pattern by regulating the number and percentage of fish that emigrated and to a limited extent time of emigration.

Movements of non-smolt trout and salmon correlated best with the amount of cover provided by large rubble substrate. Subyearling trout emigrated from Big Springs Creek which contained no rubble substrate but remained in the Lemhi River which did. In both field and laboratory tests more fish remained in troughs or stream sections with large rubble substrate than in troughs or sections with gravel substrate. Trout and salmon in many Idaho streams enter the substrate when stream temperatures declined to 4-6°C. A suitable substrate providing adequate interstices appears necessary or the fish leave."

Blackett, Roger F.
1968. Spawning behavior, fecundity, and early life history of anadromous Dolly Varden, Salvelinus malma (Walbaum) in Southeastern Alaska. Alaska Dept. Fish and Game Res. Rept. No. 6: 85 pp.

"The early life history of Dolly Varden was studied at Hood Bay Creek in 1965 and 1966. Winter Survival of eggs to yolk sac fry was estimated to be about 41 percent from hydraulic sampling of the spawning site in the spring of 1966. The rearing habits and requirements, indicated by uniform sampling methods, involve seasonal trends of intra-stream movement, habitat preferences, and differential size group preferences. Age composition and growth rate of the rearing fish appeared quite similar to that of young fish in the Lake Eva system."

Boussu, Marvin F.
1954. Relationship between trout populations and cover on a small stream. J. Wildl. Mgmt. 18(2):229-239.

"A total of 155 sq. ft. of brush cover was applied to four sections. The increase in total pounds of fish following this application averaged 1.60 per inventory. The populations in three control sections increased 0.23 pounds per inventory.

A total of 128 sq. ft. of natural brush cover was removed from two sections. The decrease in total pounds of fish per inventory following removal was 1.71. A control section increased in total pounds by an average of 0.18 per inventory.

Fifteen square feet of undercut bank was removed from two sections. The decrease in total pounds per inventory following this removal was 0.25. The control section increased in total pounds an average of 0.25 per inventory."

Brett, J. R.
1957. Salmon research and hydroelectric power development. Bull. Fish. Res. Bd. Canada No. 114:26 pp.

"It was found that sockeye and coho downstream migrants orient themselves by sight, in the presence of light and absence of turbulence. The difference in response to a currant of water in darkness and in light may be simply the absence of visual cues in the dark, rather than any diurnal change in behavior. The white water below a falls or spill must be equivalent to partial blinding."

Burns, James W.
1971. The carrying capacity for juvenile salmonids in some northern California streams. Calif. Fish and Game, 57(1):44-57.

"Standing crops of juvenile coho (silver) salmon (Oncorhynchus kisutch), steelhead rainbow trout (Salmo gairdneri), and coast cutthroat trout (Salmo clarki) were examined in seven coastal streams to define the natural carrying capacity of these streams, and to develop methods of population comparison and prediction which could be used to determine the effects of road construction and logging on salmon and trout production.

Biomass per unit of surface area was the best method of expressing carrying capacity, because biomass was better correlated with stream surface area than with other parameters tested. Volume of streambed sediments, total dissolved solids, alkalinity, and total phosphate in six streams were not

satisfactory predictors of carrying capacity. Only living-space variables correlated significantly with biomass. Not all streams reached carrying capacity in the summer and salmonid biomass was highly variable. Even with 3 years of prelogging study, it would be difficult to attribute a change in carrying capacity under 50% to anything but natural variation."

Burns, James W.
1972. Some effects of logging and associated road construction on northern California streams. Trans. Amer. Fish. Soc. 101(1):1-17.

"The effects of logging and associated road construction on four California trout and salmon streams were investigated from 1966 through 1969. This study included measurements of streambed sedimentation, water quality, fish food abundance, and stream nursery capacity. Logging was found to be compatible with anadromous fish production when adequate attention was given to stream protection and channel clearance. The carrying capacities for juvenile salmonids of some stream sections were increased when high temperatures, low dissolved oxygen concentrations, and adverse sedimentation did not accompany the logging. Extensive use of bulldozers on steep slopes for road building and in stream channels during debris removal caused excessive streambed sedimentation in narrow streams. Sustained logging prolonged adverse conditions in one stream and delayed stream recovery. Other aspects of logging on anadromous fish production on the Pacific Coast are discussed."

Butler, Robert L. and Hawthorne, Vernon M.
1968. The reactions of dominant trout to changes in overhead artificial cover. Trans. Amer. Fish. Soc., 97:37-41.

"A submerged tank at the Sagehen Creek Project of the University of California provides a facility for analysis of trout behavior under natural stream conditions. Here, studies were made to learn to what extent dominant trout will use shade provided by overhead artificial surface cover. Three overhead artificial surface covers of different size were constructed of 3/4 inch plywood. They were mounted on steel legs and painted black on the side in contact with the surface water. During each of three studies, these covers were permuted every two or three days with three different positions in the test area.

Three dominant trout representative of the three common trout, brook, rainbow, and brown, were used in three separate tests. Several brook trout and rainbow trout occupied the test area simultaneously with each dominant trout.

From 286 hours of observation it was learned that the rainbow trout showed the lowest use of shade produced by the overhead covers and the highest activity in movements from these shaded areas. Activity of the brown trout was the lowest of the three species, but the use of shade was the highest. The brook trout was intermediate in both these aspects.

All three species showed a preference for (Chi-square $P < 0.005$) the shaded areas of the large overhead cover (3 by 3 feet) versus the shaded area provided by the medium-sized overhead cover (2 by 2 feet). Very little utilization was made of the shade provided by the small overhead cover (1 by 1 foot).

The rainbow trout showed the least attachment for any particular site, whereas the brook trout and brown trout showed a preference for a particular site and overhead combination. Although these data are limited, they confirm much of what is known by the observant angler."

Carlander, K. D.

1955. The standing crop of fishes in lakes. J. Fish. Res. Bd. Canada, 12(4):543-570

"Standing crop estimates derived by draining and those by poisoning appear to be equally accurate, but marking and recovery estimates may not be directly comparable with the other two average standing crops in river backwaters and oxbows were almost 500 pounds per acre; in midwestern reservoirs, almost 400 pounds per acre; in other reservoirs and ponds, 200 to 300; in warm-water lakes, 125 to 150; and in trout lakes, less than 50 pounds per acre.

No correlation could be shown between areas of lakes or ponds and their standing crops per acre. There was a tendency for standing crop per acre to decrease with increase in maximum depth of trout lakes, of warm-water lakes, and probably of reservoirs. Significant increase in standing crop per acre with increase in carbonate content of the water was found in trout lakes, warm-water lakes and midwestern reservoirs.

Elton's pyramid of numbers was demonstrated in an analysis of standing crop per acre by species. Competition between species at the same food level may be mitigated by habitat segregation. Standing crop per acre increases as the number of species increases or as the niches are filled. However, standing crops of given species were usually highest when only one or two species were present. Regressions of the standing crops of one species upon those of other species may give clues as to the degree of competition or of protocooperation, but these clues must be critically evaluated since the regressions may be due to factors other than the presence of the other species."

Chapman, D. W.

1962. Effects of logging upon fish resources of the West Coast. Jour. Forestry. 60(8):533-537.

A summary of the effects of logging on fisheries resources and stream habitat. Items discussed are: stream flows, velocities, water temperatures, water quality and sedimentation, aquatic insects and phytoplankton, fish habitat, energy sources for production, log barriers and fish movement.

Chapman, D. W.
1962. Aggressive behavior in juvenile coho salmon as a cause of emigration. J. Fish. Res. Bd. Canada, 19(6):1047-1080.

"Large numbers of coho fry (called nomads) move downstream from shortly after emergence through early fall. These fry are smaller than residual coho. Study of behavior showed coho to be aggressive and territorial or hierarchical. Nomadic coho placed in stream aquaria barren of resident fish tended to remain in the aquaria rather than continuing downstream movement, while nomads added to resident groups of coho were dominated by the resident dominant fish and tended to leave the channels. Hierarchies were organized on the basis of fish size, with larger fry having better growth opportunities. Feeding of coho in excess of requirements did not alter holding capacity of stream aquaria. Aggression observed in natural stream areas was frequent, probably virtually continuous. Nomads transferred to natural stream areas barren of other coho remained there, while nomads added to resident populations tended to move downstream. It was concluded that aggressive behavior is one important factor causing downstream movement of coho fry."

Chapman, D. W.
1965. Net production of juvenile coho salmon in three Oregon streams. Trans. Amer. Fish. Soc. 94(1):40-52

"Net production of juvenile coho salmon was estimated in three small streams in Oregon for 4 consecutive years. Annual net production of coho was greatly different in the 4 years, but production per unit area was similar among streams, averaging about 9 g/m^2 per year. No significant differences were found among streams in production per unit area for 14 months from emergence of fry one spring through seaward migration the next spring. For 4 years biomass averaged 5-12 g/m^2 shortly after emergence of fry, declining to 2-3 g/m^2 by July and remaining at about 2-4 g/m^2 until emigration of smolts in the following spring. In all years, mean production declined from 1.9-2.8 g/m^2 per month after emergence to 0.2-0.3 g/m^2 per month in winter, then increased to 0.5-0.6 g/m^2 per month prior to emigration. Monthly instantaneous growth rates were highest shortly after emergence of fry, declining until late winter, then increasing just before smolt emigration. The mean monthly instantaneous growth rate was about 0.19 for all streams and years. Yield of smolts as seaward emigrants ranged from 18 to 67 per 100 m^2. Net production was 1.5 to 3.0 times greater than yield as biomass of smolts. Net production of all fish in one stream containing coho, steelhead and cutthroat trout, and cottids was estimated to be 16 g/m^2 per year and compared with data from other waters. Relatively large freshets appeared to cause large downstream movements of juvenile coho. Downstream drift of postemergence fry and emigration of yearlings tended to bias estimates of growth and net production in the residual populations."

Chapman, D. W.
1966. Food and space as regulators of salmonid populations in streams. Amer. Nat. 100(913):345-357.

"For stream-dwelling, natural population of salmonids, all the foregoing can be forged into one grand speculation. The physical environment only legislates the density and does not react to the biological aspects; thus, setting the framework within which density is governed. Some biological aspects of environment have the characteristics necessary for governing density. In some cases, competition for spawning sites may limit density; more usually, seeding is adequate and the control of density occurs at later stages in life history. Predation, cannibalism, pathogens, and parasites act usually as agents of destruction. Interspecific competition in stream fish acts more as a density-legislative factor than as a density-governing one because of specific habitat isolation brought about by current velocity, bottom type, cover, and time.

In summer each species is regulated in density by a space-food, sometimes by a space-shelter, mechanism. In the former case competition for space (contest) has been substituted for conventional competition for food (scramble), but the substitution is incomplete, permitting populations to make use of temporarily super-abundant food. A minimal spatial requirement appears to be present regardless of food supply and perhaps has been fixed over the evolutionary time scale by minimal food supply. If density is regulated in the winter, it probably is related to space necessary to escape downstream displacement or damage by current."

Chapman, D. W. and Bjornn, T. C.
1969. Distribution of salmonids in streams with special reference to food and feeding. Symposium on salmon and trout in streams. H. R. MacMillan lectures in fisheries, Univ. B.C. p 153-176.

"Autecology of fish distributions is treated with particular attention to behavior of young chinook salmon and steelhead trout in Idaho streams. Behaviour of other fish species and races is examined and discussed.

In the warmer months young chinook salmon and steelhead trout are associated with velocities and depths in proportion to body size, shifting to faster and deeper waters as body growth occurs. Interaction for space between species is minimal because of differing times of fry emergence. Distribution close to high-velocity water is food-related and density is socially-controlled with the greatest distributional role of social behavior played among fish of near-equal size. During the day the fish remain in a small home area, then settle at night to the bottom, generally after moving inshore.

Beginning in September many young steelhead and chinook salmon move downstream from tributaries to overwinter in larger streams, often living in the stream substrate. Most fish disappear into the substrate at temperatures below about 5 C, and winter cover is important in holding over-wintering fish.

Distributional behavior of young salmon and steelhead in the warmer months is similar to that of several other salmonid species. Winter hiding behavior is common in stream salmonids, often preceded by downstream movement in the fall. Return upstream movements in spring often occur. Such behavior in the colder months is probably directly related to water temperature."

Conte, F. P., Wagner, H. H., Fessler, J., Gnose, C.
1966. Development of osmotic and ionic regulation in juvenile coho salmon Oncorhynchus kisutch. Comp. Biochem. Physiol., 18:1-15.

"1. The developmental pattern for the osmotic and ionic regulatory system during the juvenile phase of the life cycle was determined. Measurements of survival time were made monthly as were changes in blood osmotic, sodium and chloride concentrations following exposure to sea water (salinity = 30‰).

2. The development of sea-water adaptation preceded seaward migration and parr-smolt transformation by 6-7 months. No regression of adaptation was observed following the terminal stages of the migration period.

3. Sea-water survival for various salinities (20‰→30‰) was shown to be a function of size and not chronological age. Relative survival times between certain species of the genus Salmo were compared to Oncorhynchus kisutch.

4. Variability of the osmotic and ionic regulatory system was indicated by the deviation between blood concentrations (i.e. mOsm/l, mEquiv. Na^+/l and mEquiv. Cl^-/l) of fresh-water fish (control) and fish exposed to sea water during the pre-migratory, migratory and post-migratory periods."

Cooper, E. L.
1970. Growth of cutthroat trout (Salmo clarki) in Chef Creek, Vancouver Island, British Columbia. J. Fish. Res. Bd. Canada 27: 2063-2070.

"Cutthroat trout were collected periodically from April 3 to September 20, 1968, by electrofishing and were preserved in formalin. Within a few days, each fish was measured and a sample of scales was taken for study. Scales first appeared on these cutthroat trout immediately above and below the lateral line on the anterior portion of the caudal peduncle. Scales were always selected from this area for study, mounted in glycerin-gelatin, and examined at a magnification of 127 diameters. Scales grow relatively more slowly as the fish increases in length, causing the body-scale relation to be curvilinear. Growth of the fish was determined both by calculating size-at-age data from the scales and by comparing mean lengths of age-groups collected at different times of the year.

The growth of cutthroat trout from Chef Creek was slow; calculated mean fork lengths for the first three annuli were 50, 84, and 119 mm. Only a few fish of age-group IV were collected and these were considered to be nonanadromous individuals on the basis of scale examination and small size."

Cordone, A. J. and D. W. Kelly

1961. The influences of inorganic sediment on aquatic life in streams. Calif. Fish and Game. 47:189-228.

"There is abundant evidence that sediment is detrimental to aquatic life in salmon and trout streams. The adult fishes themselves can apparently stand normal high concentrations without harm, but deposition of sediments on the bottom of the stream will reduce the survival of eggs and alevins, reduce aquatic insects fauna, and destroy needed shelter. There can scarcely be any doubt that prolonged turbidity of any great degree is also harmful."

Crone, Richard Allan

1968. Behavior and survival of coho salmon, <u>Oncorhynchus kisutch</u> (Walbaum), in Sashin Creek, Southeastern Alaska. M. S. Thesis, Oregon State University. 79 pp.

"A weir or fyke net was fished in the spring to estimate emigration of juvenile coho. Coho smolts left Sashin Creek from April through July; peak emigration occurred in late May or early June. Coho fry left the stream in the spring and summer in widely varying numbers from year to year. I estimated from growth data, population estimates, and analysis of scale samples that most coho juveniles remained in Sashin Creek for two growing seasons before migrating to sea.

Analysis of scales from juvenile coho indicated that some reabsorption of scales occurs during the winter. The possibility of reabsorption of circuli makes back-calculation of the length of younger age groups of coho from scale measurements unreliable.

Diptera were represented more often than any other order of insects in the stomachs of juvenile coho. Hemiptera were important as food items to juvenile coho in a tributary stream. The estimated survival from egg deposition to immediately prior to emergence varied between 17.5 and 34.9 percent for the three brood years, and averaged 27.8 percent. Early summer populations of fry were variable in size and dependent on the size of the egg deposition of the brood. Populations of fry declined rapidly during July and early August. Instantaneous mortality rates were much higher for this period than during any other time in the freshwater life of coho salmon in Sashin Creek. Mortality dropped to a low level during the following winter period."

Demory, Robert Leroy

1961. Foods of juvenile coho salmon and two insect groups in the coho diet in three tributaries of the Alsea River, Oregon. M.S. Thesis, Oregon State University. 68 pp.

"1. Diptera in the three streams was the most important goup of food items in terms of dry weight. They were represented mostly by Tendipididae. Other food groups of importance were Ephemeroptera in Deer Creek, Trichoptera in Flynn Creek and Hymenoptera in Needle Branch.

2. Fish in Deer Creek and Flynn Creek fed mainly on organisms of aquatic habitats, but fish in Needle Branch fed mainly on terrestrial organisms. During the summer months of 1959, fish in Deer Creek fed primarily on aquatic items, but in Needle Branch the diet was composed mainly of terrestrial items. Fish in Flynn Creek selected aquatic and terrestrial food items in about equal proportions.

3. The predominance of aquatic items in fish stomachs from Deer Creek during the summer months of 1959 was apparently due to organic drifting resulting from surface flows between pools. In Needle Branch the predominance of terrestrial items was apparently due to lack of organic drift because of little or no surface flow between pools late in the summer.

4. Generally, 0/ age fish utilized the smaller invertebrate organisms such as Tendipedid larvae, Collembola and small mayfly nymphs. Trichoptera and other larger insects were utilized mainly by 1/ age fish.

5. Baetis nymphs were predominately algal feeders, diatoms being the dominate algal forms present in the stomachs. Amounts of algae available to Baetis nymphs were limited by reduced light levels due to cover densities.

6. Paraleptophlebia nymphs were predominately detritus feeders during daylight hours because of a strong negative-phototropic response. Two night sampling experiments indicated that these nymphs fed to a greater extent on algae at night.

7. Examination of Hydrobaenid larvae indicated that they were primarily detritus feeders and fed only to a limited extent on algae."

Doudoroff, P. and D. L. Shumway.
1967. Dissolved oxygen criteria for the protection of fish. In: A symposium on water quality criteria to protect aquatic life. Amer. Fish. Soc. Special Publ. No. 4:13-19.

In laboratory studies, swimming ability and rates of development and growth have been shown to be limited by the oxygen supply at oxygen concentrations very near or even well above saturation levels.

Edgington, John Richard.
1969. The impact of logging on the ecology of two trout streams in North Idaho. M.S. Thesis. Univ. Idaho, 73 p.

"4. No unfavorable conditions were found in dissolved oxygen, pH or hardness in the control or test streams for either study area.

5. Turbidity measurements were high during road building in 1957 in Crystal Creek and increased sedimentation was noted. Turbidities in 1966 were low for all streams.

6. No effect on cutthroat trout population was detected that could be attributed to logging.

7. Trends in abundance of the four most important Orders of aquatic insects in the St. Joe study streams appeared normal over the years. No effect from logging was noted in this area.

8. A downward trend after road building was most clearly noted for volumes of Plecoptera following road construction in the Crystal Creek area. Ephemeroptera and Trichoptera also trended downward. Insects in the control stream (Silver Creek) had similar although less pronounced trends in volumes. It appears that weather conditions may also have been affecting the bottom fauna of the area.

9. Both streams have either reached the pre-logging level of bottom fauna abundance or have shown an increase."

Edmundson, Eldon, Everest, F. E. and Chapman, D. W.
1968. Permanence of station in juvenile chinook salmon and steelhead trout. J. Fish. Res. Bd. Canada. 25(7):1453-1464.

"Daytime movements and night locations of juvenile steelhead trout (Salmo gairdneri) and night locations of spring-run chinook salmon (Oncorhynchus tshawytscha) were observed in Johnson Creek and the Lochsa River in Idaho during the summers of 1965 and 1966. The observations were made by branding fish and observing them subsequently under water. The distances between sequential sightings of branded steelhead within each day and over longer periods were recorded. In 151 sequential sightings of steelhead within each day in Johnson Creek, 58% of the distances moved were less than 3 m and 86% were less than 6m. In 59 sequential sightings of branded steelhead on successive days in the Lochsa River and Johnson Creek, 53% were less than 3 m and 68% were less than 6 m apart. In sightings of branded steelhead separated by 10-14 days, 45% (25) of the sequential sightings were less than 3 m and 63% were less than 6 m apart. Movements of spring-run juvenile chinook salmon within each day were measured in a stream aquarium (10.5 m long and 0.6 m wide). Of 272 observed daily movements, 65% were less than 0.6 m. Steelhead trout were inactive at night, occupying bottom areas of low velocity, usually inshore. During the day they were in areas of moderate current. Chinook salmon were observed at night to be both on the bottom and near the surface in quiet water, and on the bottom in flowing water. Chinook salmon were found at all depths in quiet water during the day. In winter, some steelhead trout were found in the substrate in the same area they occupied the previous summer."

Elliott, J. M.
1967. The food of trout (Salmo trutta) in a Dartmoor stream. J. Appl. Ecol., 4, p. 59-72.

"1. The food of trout (Salmo trutta) was investigated in relation to the invertebrate drift and the benthos.

2. Using an electrical stunning machine, fish samples were taken from June 1963 to October 1964 in the day and from April to October 1964 at night.

3. Nearly all the common members of the benthos and drift occurred in the trout stomachs, but only 1+ and 2+ trout contained the larger members of the benthos and drift. The biomass and numbers of most items in the stomachs increased with the size of the trout, and showed no definite pattern when compared on a monthly basis.

4. The principal day foods were nymphs of Baetis spp. for 0+ trout, terrestrial invertebrates and oligochaetes for 1+ trout, and large larvae of Limnephilidae for 2+ trout. It is suggested that this marked difference in the principal foods reduced the competition for food between the fish classes.

5. Most of the animals taken exclusively from the drift were only important as constituents of the diet in summer, and those taken chiefly from the benthos were important in both winter and summer. Some animals were taken from both drift and benthos in large numbers, especially in winter.

6. The fish samples taken at night indicated that the trout were feeding in the early hours of the night during the summer months. It is concluded that the availability of many benthic animals increased at night and that the trout were utilizing this readily available food either as drift or from the tops of stones."

Elliott, Steven T. and Robert H. Armstrong
1972. Dissemination of information collected on Dolly Varden. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1971-1972, Project F-9-4, 13(R-IV):In print.

"Interspecific and intraspecific competition was observed in Dolly Varden-coho communities with coho fry and Dolly Varden fingerlings being the most aggressive.

Dolly Varden and coho communities appear to be vertically segregated, with rearing char feeding closer to the substrate and coho feeding at the surface.

Rearing fish population densities were influenced more by intraspecific competition than interspecific competition.

The food habits of rearing fish appear to remain fairly constant during the rearing period.

Both species of fish utilize invertebrate drift for food, coho to a much greater extent that Dolly Varden.

Dolly Varden may feed selectively on Chironomidae larvae.

This report presents the results of information collected at Hood Bay Creek, southeast Alaska from May 1968 through May 1971 on rearing Dolly Varden (Salvelinus malma) and coho salmon (Oncorhynchus kisutch). Emphasis of the study was placed on competition, food habits, and habitat requirements of the rearing fish.

Rearing Dolly Varden and coho were distributed throughout Hood Bay Creek with young char appearing to prefer undercut banks as habitat and more coho distributed in sloughs, backwaters, and slow moving tributaries. Fry of both species were commonly found along stream margins and small tributaries.

Both species of rearing fish appear to move to the warmer headwater tributaries to overwinter. During the winter fewer Dolly Varden feed than do coho."

Everest, Fred H.
1969. Habitat selection and spatial interaction of juvenile chinook salmon and steelhead trout in two Idaho streams. Ph. D. thesis, Univ. of Idaho. 77 pp.

"A survey of 2840 m^2 of habitat in 1966 indicated that during summer coexisting populations of these species are segregated. Age 0 steelhead were most abundant over rubble substrate at velocities and depths of less than 0.15 m/sec and 0.15 m, respectively; densities of age 0 chinook were maximal over silt substrate at velocities of less than 0.15 m/sec and depths of 0.15-0.3 m; age 1 steelhead were most abundant over large rubble substrate at bottom velocities and survace velocities of 0.15-0.3 m/sec and 0.75-0.9 m/sec, respectively, and depths of 0.6-0.75 m. In 1967, habitat occupied by allopatric populations of each species was sampled to see if segregation was the result of interspecific interaction. The results of this work did not demonstrate an interactive segregative mechanism, but instead indicated that the presence of one species had little impact on distribution of the other. Juvenile chinook and steelhead of the same size were found to have similar ecological demands. But, steelhead spawn in spring and chinook spawn in early fall, creating intra- or interspecific size groups of pre-smolts and minimizing the potential for interaction. Individuals of both species hibernate in rocky areas of the stream bottom (particle size >40 cm) in winter."

Everest, F. H. and D. W. Chapman
1972. Habitat selection and spatial interaction by chinook salmon and steelhead trout in two Idaho streams. J. Fish. Res. Bd. Canada 29:91-100

"During summer sympatric steelhead trout and summer chinook salmon segregated in Crooked Fork and Johnson creeks. In short-term allopatry, each species occupied the same types of habitat as in sympatry. Most age 0 steelhead lived over rubble substrate in water velocitites and depths of less than 0.15 m/sec and 0.15 m, respectively; most age 0 chinook lived over silt substrate in water velocities of less than 0.15 m/sec and depths of 0.15-0.3 m; most age I steelhead resided over large rubble substrate in water velocities of 0.15-0.3 m/sec (near bottom) and 0.75-0.9 m/sec (near surface), and in depths of 0.6-0.75 m. As fish of each species became larger they moved into faster, deeper water. Juvenile chinook and steelhead of the same size used the same physical space. But steelhead spawn in spring and chinook spawn in early fall, and disparate times of spawning create discrete intra- and inter-specific size groups of pre-smolts. The size differences minimize potential for social interaction, both intra- and inter-specific."

Fraser, F. J.

1969. Population density effects on survival and growth of juvenile coho salmon and steelhead trout in experimental stream channels. Symposium on Salmon and Trout in streams. H. R. MacMillan Lectures in Fisheries. Univ. of B.C. pp. 253-265.

"In nature, coho salmon and steelhead trout are closely associated in their first year of life. This association, combined with initial high densities, must play an important role in determining growth and survival. This study was designed to measure density effects upon the population dynamics of these fry. Three hypotheses were tested: (1) that growth rates are density-dependent, (2) that survival rate is largely species-specific and, (3) that interspecific competition will be less intense than intraspecific competition.

Steelhead fry have a faster initial growth rate than coho, enabling them to exceed the coho in growth despite the latter's earlier hatching and consequent initial size advantage. Growth rates were inversely related to density, both inter- and intraspecific effects being noticeable. Survival data indicated that this aspect of their population dynamics was largely species-specific.

The effects of competition, both inter- and intraspecific, were found to be greatest within the high-density group, where minimal biomass was produced. The effects were much less within the intermediate groups where competition was almost entirely intraspecific. The low-density groups experienced minimal competition."

Fujihara, M. P., P. A. Olson, and R. E. Nakatani.
1971. Some factors in susceptibility of juvenile rainbow trout and chinook salmon to Chondrococcus columnaris. J. Fish. Res. Bd. Canada 28:1739-1743.

"Susceptibility of juveniles of chinook salmon (Oncorhynchus tshawytscha) and rainbow trout (Salmo gairdneri) to Chondrococcus columnaris disease appeared to be influenced by age of fish, crowding, and water temperature. Rainbow trout of about 1 g and chinook salmon of about 3 g were less susceptible than smaller fish, and tests with chinook salmon suggested that age was more important than weight. When chinook salmon averaging 4.3 g were exposed from July to October to the pathogen in river water, mortality ranged from 1.0% in a trough with 50 fish to [illegible] in one with 900. Mortality of rainbow trout averaging 2.4 g that were exposed to the pathogen in trough river water averaged 4.7-22% after 4 weeks, at temperatures from 17.2 to 17.8 C; the survivors, however, were generally resistant to subsequent infection, suggesting development of an immune response. Times to 100% mortality of sibling chinook salmon averaging [illegible] g that were exposed for 25 min to about 2.5 x 10^5 organisms per liter of sterile river water were about 19 hr at 10 C and 8 hr at 22 C. Survival of rainbow trout was higher when they were held at 2.2 degrees C below than when held at 2.2 degrees C above seasonal river temperatures."

Goodnight, W. H. and Bjorn, T. C.
1971. Fish production in two Idaho streams. Trans. Am. Fish. Soc. 100(4):769-780.

"We estimated fish production (tissue elaboration) in two tributaries of the Salmon River in Idaho. Fish in Big Springs Creek produced 11.8 $g/m^2/yr$ and in the Lemhi River 13.6 $g/m^2/yr$. In Big Springs Creek juvenile rainbow-steelhead trout comprised most (84-95%) of the biomass present and contributed most of the production (88%). In the Lemhi River, however, a large population of unexploited whitefish made up most (60-80%) of the biomass but they contributed only 52% of the production. The desired yield from Big Springs Creek, an intensively managed stream, was steelhead trout smolts and the weight of the juvenile migrants was 34% of total production in the stream. In the Lemhi River, chinook salmon smolts were the primary desired yield and weight of smolts was probably less than 11% of total production. Virtually no yield was obtained from the whitefish population in the Lemhi River."

Data also suggests that possibility that both Brook trout and steelhead [illegible] overwinter in small tributaries and return to the main creek during [illegible].

[illegible]
[illegible]. The coho salmon (Onchorhynchus kisutch, Walbaum). A biological sketch. Isvestiya TINRO 28:43-101. Fisheries Res. Bd. of Canada Translation Series No. 370.

Emergence of coho fry from the gravel occurred from March to July with fry averaging approximately 27-32 mm. Yearling and two year old coho measure 35-115 mm and 55-125 mm in length respectively. Scale circuli counts for young coho average as follows: Age I summer, 4; winter 4; Age I+ 1st summer 6; 1st winter 6; 2nd summer 3; Age II+ 1st summer 5; 1st winter 7; 2nd summer 7; 2nd winter 5; 3rd summer 5. The ratio of yearlings to two year olds in all sample areas ranged from 66%-100%.

Newly emerged coho were usually found in quiet backwaters, in shady areas near overhanging vegetation or near underwater cones. Larger fingerlings were found in deep quiet reaches. Most of the fish move into deep water during the winter.

Griffith, J. S., Jr.
1972. Comparative behavior and habitat utilization of brook trout (Salvelinus fontinalis) and cutthroat trout (Salmo clarki) in small streams in northern Idaho. J. Fish. Res. Bd. Canada. 29:265-273.

"Individual brook (Salvelinus fontinalis) and cutthroat (Salmo clarki) trout communicated with similar behavioral signals, both in laboratory stream-channels and in northern Idaho streams. Underyearling brook trout were less active socially than equal sized cutthroat trout in laboratory observations. In study streams, brook trout maintained a 20 mm size advantage over cutthroat of the same age groups throughout their lives, as they emerged from the gravel before cutthroat. Because of this size advantage, underyearling brook trout of sizes found in study streams in September consistently dominated in experiments the underyearling cutthroat with which they normally lived. But in study streams underyearlings of the two species utilized different microhabitats, particularly with respect to water depth, and so minimized chances for interaction.

Yearling and older brook trout initiated 40% fewer aggressive encounters under laboratory conditions than did equal sized cutthroat trout, and did not displace the cutthroat. In study streams with sympatric populations, cutthroat trout of these age groups occupied territories with focal points of higher water velocities (averaging 10.2-10.3 cm/sec) than those occupied by brook trout (averaging 7.6-9.6 cm/sec). Considerable interspecific overlap in other habitat characteristics occurred for trout of age group I and II. The oldest members of the two species segregated more distinctly, as the brook trout lived closer to overhead cover."

Gritsenko, O. F.
1969. Diet of the char (Salvelinus alpinus (L.)) in the rivers of Sakhalin. Prob. Ichthyology. Vol. 9, No. 3, p. 410-417. American Fisheries Society (Translation).

"Eggs and young salmon of the genus Oncorhynchus constitute the basic food of the char, Salvelinus alpinus (L.), in the rivers of Sakhalin. The times and duration of feeding of the char are determined by the time of appearance of this food and its abundance, factors which differ substantially in the rivers of different types depending on the species of salmon involved and their spawning times. Salmon losses caused by char predation on the young stages are not great, since the char consumes mainly inviable eggs and weak young."

"Artic char may provide a hygenic function in streams by eating dead eggs and fry".

Hartman, G. F.
1958. Mouth size and food size in young rainbow trout, Salmo gairdneri. Copea No. 3, 233-234.

Studies indicate that three types of food; trout fry, trichoptera larvae, and stonefly nymphs are injested successfully in decreasing order, respectively. Since the three organisms offer varying degrees of resistance to injestion, when related to the mouth size of the predator.

Hartman, G. F.
1963. Observations on behavior of juvenile brown trout in a stream aquarium during winter and spring. J. Fish. Res. Bd. Canada, 20(3):769-787.

"Observations were carried out in February-March and May-June periods during which water temperature ranges were 0.0-0.5°C and 8.5-12.5°C, respectively. Responses of fish to structures representing simplified environmental features, e.g. visual reference points, support against which fish could brace themselves in current, areas of slow water, overhead cover and areas of shade, were studied at three different water velocities. Winter and spring responses to illuminated and dark cover and to areas of rocky bottom were compared. Fish associated progressively more with experimental structures as more environmental features were incorporated into them. Degree of association with such structures and with other types of cover was much greater during winter. Degree of association increased with water velocity during both spring and winter. Increasing water velocities modified aggressive behavior. Fish displayed relatively more at low water velocities and nipped more at high velocities. It is possible that the association with and defence of specific locations on the bottom of a stream has selective value that alternates seasonally, providing the species with protection from predation and from displacement by current in winter, and with an efficient mode of food utilization in spring and summer."

Hartman, G. F.
1965. The role of behavior in the ecology and interaction of underyearling coho salmon (Oncorhynchus kisutch) and steelhead trout (Salmo gairdneri). Fish. Res. Bd. Canada Vol. 22, No. 4, p 1035-1081.

"Two similar salmonids, coho and steelhead, cohabit many coastal rivers of British Columbia. Field collections reveal that the distributions of underyearling coho and steelhead are similar along the length of these streams. However, the micro-distribution of the two species is different. In spring and summer, when population densities are high, coho occupy pools, trout occupy riffles. In autumn and winter, when numbers are lower, both species inhabit the pools. Nilsson (1956) stated that segregation (such as that shown by coho and trout in spring and summer) may be indicative of competition resulting from similar ecological demands. To test this hypothesis the distribution and behavior of coho and steelhead were compared in a stream aquarium at different seasons with gradients of light, cover, depth or depth/velocity, and in experimental riffles and pools. Distributions and preferences of the two species in the experimental environments were most similar in spring and summer, the seasons when segregation occurred in nature, and least similar in autumn and winter, the seasons when the two species occurred together in nature. Spring and summer segregation in the streams is probably the result of interaction which occurs because of similarities in the environmental demands of the species and which is accentuated by dense populations and high levels of aggressiveness. The species do not segregate in streams in winter because certain ecological demands are different, numbers are lower, and levels of aggressiveness are low. When the two species were together in the experimental riffle and pool environment, trout were aggressive and defended areas in riffles but not in pools; coho were aggressive in pools but less inclined to defend space in the riffles. These differences in behavior probably account for the distribution of trout and coho in natural riffles and pools.

The data support the basic contention of Nilsson (1956) and illustrate the role of behavior in segregation produced by competition for space."

Hartman, G. F. and Gill, C. A.
1968. Distributions of juvenile steelhead and cutthroat trout (<u>Salmo gairdneri</u> and <u>S. clarki clarki</u>) within streams in southwestern British Columbia. J. Fish. Res. Bd. Canada. 25(1):33-48.

"Trout were collected and identified from 66 streams or stream systems of different size and gradient. Total sissolved solids (T.D.S.) and pH were determined on most streams. Size and profile of streams to a large degree determined the species of trout present. Large streams, with drainage area over 130 km^2, were predominantly occupied by steelhead. Small streams, drainage area under 13 km^2, were predominantly occupied by cutthroat. Streams less than 120 km^2 in drainage area with steep gradients, and emptying directly into the sea, usually supported steelhead, as did large rivers. Those which dropped steeply and then levelled and ran through several miles of sloughs usually supported cutthroat. Where both species occurred, cutthroat were most often predominant in the small tributaries and headwaters, and steelhead in the lower reaches of the main stream. Stream pH's were usually lower in winter than in summer, but had no obvious effect on trout distribution. Many cutthroat streams had high T.D.S. readings in the lower reaches in summer and low T.D.S. readings in these areas in winter. Otherwise there were no marked differences between steelhead and cutthroat streams in terms of T.D.S."

Heiser, David W.

1966. Age and growth of anadromous Dolly Varden char *Salvelinus malma* (Walbaum) in Eva Creek, Baranof Island, Southeastern Alaska. Alaska Dept. Fish and Game Res. Rep. No. 5:29 pp.

"The age and growth of Dolly Varden were determined from random samples collected at the Eva Creek weir in 1962 and 1963. Otoliths were used for all age determinations. The youngest migrant char were from age group II, the oldest from age group XI, and the majority from age groups III through V. By sex, the ratio was nearly equal in the young fish with an increase in percent of females in the older age groups. The char from the Eva Creek - Lake system matured by their fifth or sixth year. The majority of the Lake Eva char spent their 0, I, II and sometimes III years in fresh water and migrate to sea in their third or fourth year of life. During this rearing period their growth was very slow. Growth between the out- and in-migrations at Eva Creek averaged 44 mm and 0.30 pound. Very little growth was exhibited by the char during their winter stay in Lake Eva. The age composition of char entering a lake system and a non-lake system was compared and discussed."

Hess, A. D. and Rainwater, J. H.

1939. A method for measuring the food preferences of trout. Copea. No. 3:154-157.

Fingerling brook trout of about 9-11 cms were fed 4 types of organisms: *Acroneuria*, *Hydropsyche*, *Chironomus*, and *Chaoborus*. These organisms are listed in descending order as to the amount of chitenization on the body. It was found that *Acroneuria* nymphs were the most difficult to digest and taking the greatest amount of time for complete digestion, while *Chaoborus* taking the least amount of time.

Hoar, William S.

1958. The evolution of migratory behavior among juvenile salmon of the genus *Oncorhynchus*. J. Fish. Res. Bd. Canada 15(3):391-428.

"The discussion is based on a detailed ethological comparison of four species of juvenile *Oncorhynchus*-coho, chum, sockeye and pink salmon. Their behaviour is described in terms of five fixed behaviour patterns-hiding under stones, occupying territories,schooling, feeding and escaping predators. These are performed in relation to five directive factors-light, temperature, current, salinity and objects in the environment. The internal motivation seems to have an endocrinological basis. The coho fry, because of its river habitat, territorial behaviour, low nocturnal activity and smolt transformation, is considered to show behaviour nearest to that of the parental type of the genus. The pink fry has the most highly specialized sea-going behaviour. Three major developments are evident in the evolution of obligatory pelagic and ocean dwelling species (a) early smolt transformation (b) increased nocturnal activity and (c) schooling. Some possible evolutionary sequences are considered."

Hopkins, C. L.

1970. Some aspects of the bionomics of fish in a brown trout nursery stream. Fish. Res. Bull. No. 4, Fish. Res. Div., New Zealand Marine Dept.

"The population density, growth, and food have been described for the members of a mixed population of juvenile brown trout, bullies, and eels. The data presented have been used to examine the ecological and competitive food relations of these species.

The food of all species of fish was the stream benthos, and most of the animals eaten belonged to the Ephemeroptera and Trichoptera. The invertebrate fauna was of "average richness" on the grading used for North American streams and in both density and biomass surpassed that of the Horokiwi, which has been considered to be similar to many New Zealand streams.

A consideration of the daily food requirements of the fish and the availability of food led to the conclusion that under normal conditions food was not a limiting factor among the adults and large juveniles. There seemed little interspecific competition for food, for living space, or for spawning sites.

It was considered that predation by larger fish on smaller was insignificant. Yet 90 percent of young bullies and trout were lost during the first few months of life; so intense intraspecific competition among very young fish was postulated. During the period of highest mortality these young fish were present in large numbers, shared the same food requirements, and apparently ate a limited variety of food items. Under these conditions the availability of food and of living space were probably the principal factors governing their survival.

There appeared to be several mechanisms operating among the young fish to reduce the likelihood of a general food shortage. Among the trout fry, territorial behaviour ensured dispersal of fish and reduced feeding pressure. Among bully fry, which showed no obvious territorialism, there was evidence of migration by some members down stream from the breeding area; moreover the protracted breeding season gave rise to a year class of large size range which might be expected to eat a wide range of food."

Huntsman, A. G.

1945. Migration of salmon parr. J. Fish. Res. Bd. Canada 6(5):399-402.

"Some salmon (Salmo salar) parr in a stream descend from the spawning areas, particularly during freshets, to populate lower waters, such as lakes and fresh or brackish parts of estuaries, although killed by full sea water. Thence they ascend and populate available streams at variable distances, depending upon conditions such as falls."

Therefore, Atlantic salmon parr have the ability to occupy streams other than their home stream for rearing purposes.

Idyll, Clarence
1942. Food of rainbow, cutthroat, and brown trout in the Cowichan River system, B. C. J. Fish. Res. Bd. Canada. 5(5):448-458.

"Stomach contents of 293 rainbow, 160 cutthroat and 113 brown trout were examined and analyzed according to species, size groups (5 cm.) and habitat (river or lake). For rainbows of both river and lake (4 to 50 cm. in length), insects, chiefly Trichoptera and Simuliidae, were predominant in all size groups. Fish constituted a small fraction of the food except in the winter when salmon eggs were available. River cutthroat subsisted chiefly on insects (Trichoptera) up to 15 cm., on insects and fish (Gasterosteus) up to 30 cm., thereafter largely on fish. Lake cutthroat samples did not eat fish in any number until 41 cm. long. Brown trout ate chiefly insects (Trichoptera) up to 45.5 cm., thereafter turning more definitely to a fish (salmonid) diet. The cutthroat were more piscivorous than the brown trout. A definite selection of food by the trout was indicated."

Jenkins, Thomas M., Jr.
1969. Night feeding of brown and rainbow trout in an experimental stream channel. J. Fish. Res. Bd. Canada 26: 3275-3278.

"This study sought to determine if stream living brown and rainbow trout (Salmo trutta and Salmo gairdneri) will feed on drifting terrestrial insects at night. Groups of fish were confined in segments of a rocky substrate mountain stream, and marked ants were introduced to the current from observation towers equipped with feeding tubes. After the last introductions of an experiment, the fish were removed and their stomachs were examined for marked ants.

Although fish of both species fed at night, they appeared to take a smaller percentage of the ants provided than did day-feeding groups studied for comparison. Fish feeding under bright moonlight and starlight captured introduced ants at about the same rates. The results suggest that trout in the type of stream studied feed or are in feeding readiness at nearly all hours of the day or night, at least in the summer months."

Jenkins, T. M., Jr., C. R. Feldmeth, and G. V. Elliott.
1970. Feeding of rainbow trout (Salmo gairdneri) in relation to abundance of drifting invertebrates in a mountain stream. J. Fish. Res. Bd. Canada 27: 2356-2361.

"Hatchery-reared rainbow trout, deprived of food for 48 or 96 hr and released in a mountain stream for 5- or 10-hr periods, consumed aerial invertebrates in numbers loosely associated with their seasonal and hourly abundance in the drift. The same was generally true for benthic insects, except that on several days feeding was much poorer relative to drift from 3:00 a.m. to 8:00 a.m. than at other times of day.

In September and October tests, aerial forms were abundant during daylight, and benthic forms abundant at night, enabling trout to feed 24 hr a day. Day and night feeding in September were roughly equal in importance, but in October more food was taken during the day. Aerial invertebrates were so rare in December that benthic insects were the most important prey day and night. However, even benthics were not numerous enough to provide good feeding."

Kalleberg, Harry
1958. Observations in a stream tank of territoriality and competition in juvenile salmon and trout (Salmo salar L. and S. trutta L). Rept. Instit. Freshw. Res. Drottningholm. No. 39:55-98.

An excellent source of information on territoriality, description of the station, boundaries and size of the station, fixation and permanence of the territory. Kalleberg also describes the activities within the territory such as feeding, size of feeding area, durinal rhythms, agonistic displays, sham and real fighting. The development of aggressiveness and territoriality in the individual and the relationships of territoriality and schooling are discussed. Kalleberg also deals with interspecific and intraspecific competition.

Keast, Allen and Webb, Deirdre
1966. Mouth and body form relative to feeding ecology in the fish fauna of a small lake, Lake Opinicon, Ontario. J. Fish. Res. Bd. Canada, 23(12):1845-1874.

"In 14 cohabiting fish species in a small freshwater lake, mouth and body structures combine with food specializations and habitat preferences to greatly restrict interspecific competition within the fauna.

The species differ quantitatively in a large number of structures and, individually and in combination, these are clearly adapted for distinctive roles. The mouth is particularly plastic, varying in position, in aperture width, and in overall form, with structures as diverse as a scoop, a beak, and a tube being found. Six basic body types occur and these, combined with varying in morphologies, result in a range of distinctive forms, including the following. Micropterus salmoides, with a compressed fusiform body and a wide mouth, is a strong-swimming, widely ranging piscivore. Notemigonus crysopterus, with a long, slender caudal peduncle, subfalcate pectoral fins, and a deeply forked caudal fin, has great maneuverability that permits it to catch individual zooplankters. Lepomis macrochirus is a "sedentary" gibbose-bodied water-hanger. Umbra limi has a stubby, cylindrical body that favours life in dense vegetation. Labidesthes sicculus, with an almost straight dorsal line to the body, a low dorsal fin, and a beak-like snout with tweezer-like teeth, is modified for surface feeding and leaping out of the water. Ictalurus nebulosus has chemotactile barbels that favour bottom feeding and paired fins that function partly as hydrofoils, keeping the body inclined downwards as the mouth sweeps the bottom.

The structural specializations give their owners a decided ecological advantage in certain situations. Only a few species, however, are limited by them to restricted ways of life. In most cases, a considerable measure of feeding flexibility is retained, presumably important for survival in cold temperate lakes."

Kionka, B. C. and Windell, J. T.
1972. Differential movements of digestible and indigestible food fractions in rainbow trout, Salmo gairdneri. Trans. Amer. Fish. Soc. 101 (1):112-115.

Rates of gastric evacuation of digestible organic material, chitin, and organic matter ranged from 80-91% after 16 hours in the stomachs of rainbow trout. The study shows that chitin is evacuated from the stomach more slowly than digestible organic matter. The delay in gastric removal of pieces of chitin is attributed to their size, with smaller pieces moving freely and large pieces being retained.

Lantz, Richard L.
1970. Effects of logging on aquatic resources. Oregon State Game Commission. Res. Div. Rept. pp. 13-16.

Contains information on the effects of logging on rearing coho and sea-run cutthroat. "The primary changes observed after logging have included (1) an increase in stream temperature, (2) a decrease in dissolved oxygen levels in the surface waters during the summer when logging debris was in the stream, (3) a decrease in the permeability of the intragravel environment during the time that salmonid embryos were developing in the gravel, (4) an increase in suspended sediments, and (5) a decrease in the cutthroat trout population."

Larkin, P. A.
1956. Interspecific competition and population control in freshwater fish. J. Fish. Res. Bd. Canada 13(3):327-342.

Interspecific competition is defined as the demand of more than one organism for the same resource of the environment in excess of immediate supply. When two species are "competing for a niche" the term competion has been used to include phenomena such as predation of the two species on each other, competition to avoid a parasite, etc. Making this distinction in natural situations is unrealistic. In the limited sense in which interspecific competition is defined above, it is a discrete phenomenon, which with other phenomena such as predation, can be measured as a factor involved in interaction between species.

Freshwater environments offer comparatively few opportunities for specialization in fishes. In consequence many species have a relatively wide tolerance of habitat type, a flexibility of feeding habits and in general share many resources of their environment with several other species of fish. Cannibalism and mutual predation are common complications of competitive relationships between species. The organization of freshwater fish communities is thus characterized by breadth at each level of the food chain rather than by a height of a pyramid of numbers. Flexible growth rate and high reproductive potential permit fish populations to tide over unfavorable periods of competition. In these circumstances it is difficult to separate the role of interspecific competition from other phenomena as a factor of population control. As a subordinate factor, predisposing fish to loss from other causes, interspecific competition may act to influence population levels. There is need for quantitative data and mathematical models for study of the types of population interaction typical in freshwater fish associations."

Lindroth, Arne
1955. Distribution, territorial behavior, and movements of sea trout fry in the River Indalsalven. Rept. Instit. Freshw. Res. Drottingholm. No. 36:101-119.

"The sea trout fry population of the river Indalsalven was studied by electrofishing, marking experiments and stream tank observations.

The trout fry was found to occupy the shallow water (0-3 dm deep) border line of the river, where the water ripples over stones and gravel. Facts are presented indicating that the trout actively drives the salmon fry away from these chosen areas.

Observations in a stream tank have shown the territorial behaviour to be dependent on water velocity. This circumstance explains the field experience that trout fry are very rarely seen locked up in shore pools by falling water level - before being imprisoned they leave their territories.

Marking of over 1,200 fry showed that trout parr population to be unstable, undertaking extensive horizontal movements."

Lindstrom, Thorolf
1955. On the relation fish size-food size. Rep. Instit. Freshw. Res. Drottningholm. No. 36:133-147.

"Plankton in some lakes is too scarce to be the main food of char fry when the fry start feeding in late winter and spring. Aquarium experiments show that char fry can consume food items of very different kinds as long as the items are moving. The food of adult char from some lakes is studied and the lake plankton is analyzed (Samples: 5-5.3 liters). Attention is paid to the seasonal variation and the variation between depths between stations in plankton abundance and plankton composition. It is not possible to compute a forage ratio and to analyze this material statistically. Nevertheless the material suggests that the adult char selects a) Cladoceres and b) large types of plankton Crustacea (Bytotrephes, adult Daphnia females, Bosmina, Hiterocope). The mechanism and the significance of food selection is discussed.

Certain foods indicate that char inhabits the top layers of the lakes studied when feeding on plankton."

Lister, D. B. and Walker, C. E.
1966. The effect of flow control on freshwater survival of chum, coho, and chinook salmon in the Big Qualicum River. Can. Fish. Cul. Vol. 37:3-26.

"An environmental control project has been undertaken on a British Columbia coastal stream by the Department of Fisheries of Canada to increase the production of native chum, coho and chinook salmon populations. The works which have been constructed provide for stabilization of winter flows, increase in the minimum summer flow, and a degree of temperature control during summer and early fall. The freshwater survival rate of each species during a four year period of natural flow conditions is compared with that resulting from the first two years controlled flow. Chum salmon egg-to-fry survival ranged from 5 to 17 percent under natural conditions and was inversely related to the peak daily discharge during the incubation period. Survival rates in the two years of flow control were 25.2 percent and 24.5 percent respectively. The magnitude of the coho fry emigration near the river mouth was also related to winter discharge stability. Coho spawning populations of similar size, but affected by differing incubation conditions, produced fry emigrations amounting to 0.3 percent (natural flow) and 4.3 percent (controlled flow) of their respective egg potentials. Little variation occurred in coho smolt output over a five year period. Chinook salmon survival ranged from as low as 0.2 percent under natural conditions to 19.8 percent in one year of controlled flow. The largest production of chinook emigrants was accompanied by a substantial change in quality toward smaller size and earlier migration timing."

Lorz, Harold W.
1970. Brown trout ecology. Oregon State Game Comm. Res. Div. Rept. Fed. Aid. F-82-R. pp. 6-8.

Information is given on length frequency, age, and population densities of rearing brown trout in the Deschutes River system.

Lowry, Gerald R.
1965. Movement of cutthroat trout, Salmo clarki clarki (Richardson) in three Oregon streams. Trans. Amer. Fish. Soc. 94:334-338.

"Upstream migrations of trout occurred from late October until March, with a maximum in December. Kelts returned downstream from December to April with the greatest numbers in January and February. More than 90% of the downstream movement of immatures occurred February, March, April, and May, with numbers being consistently greatest in April. Two-year-old immature fish dominated the run in the two larger streams, while 1-year-old immatures did so in the smallest stream.

Small tributaries of the study areas were found to be very important to cutthroat trout reproduction. Yound trout were noted to leave the tributaries at about 1 year of age. Trout 150 mm in length that had never left the study streams were found in a gravid condition near redd site."

Lowry, G. R.
1966. Production and food of cutthroat trout in three Oregon coastal streams. J. Wildl. Manag.. 30(4):754-767.

"The mean annual biomass of coastal cutthroat trout for all streams was 4.2 grams per square meter (g/m^2). Growth in length was greatest in April and May and least in October and November. Production per year averaged 4.1 g/m^2 for the three streams, but production levels were about 20 percent higher in one of the three. Food samples from trout stomachs taken during the period of emergence and early growth of coho salmon (Oncorhynchus kisutch) fry suggested that cutthroat trout were not important consumers of young coho. Aquatic arthropods were consistently an important part of the diet; earthworms decreased in importance and terrestrial arthropods increased in importance during the period February-June."

Lowry, Gerald R.
1971. Effect of habitat alteration on brown trout in McKenzie Creek, Wisconsin. Dept. Natural Resources, Res. Rept. 70., Fed. Aid Wildl. Res., Project F-83-R.

A study of McKenzie Creek, Polk County was conducted for 8 years to determine if the brown trout population benefitted from such deliberate habitat changes as installation of current deflectors and cover devices, bank revetment, brush felling and removal of beaver dams. Increases in number of brown trout were observed following habitat alteration. The changes in catchable sized fish were relatively small and could not be definately ascribed to the deliberate habitat alteration. The observed changes in number of trout may have been affected by uncontrolled and unmeasured variables in the natural stream environment. Alterations that mainly increase cover on relatively undamaged streams will probably not result in dramatic increases in the number of catchable sized trout.

Mason, J. C. and Chapman, D. W.

1965. Significance of early emergence, environmental rearing capacity, and behavioral ecology of juvenile coho salmon in stream channels. J. Fish. Res. Bd. Canada 22(1):173-190.

"Coho behavior was examined in two glass-walled stream channels containing riffle-pool series. The apparatus permitted volitional residence. Experimental groups of coho in each channel were permitted to emerge from a simulated redd environment and subsequently studied for 5 months.

Aggressive behavior in these coho fry was initiated within 1 week of emergence from the gravel. Within 10 days of emergence, coho occupied and defended feeding territories well-distributed in riffles. Initial aggression was nipping and chasing but within 2 weeks of emergence, aggression also involved threat.

Pools appear to constitute principal security features of coho environment. A behavioral pattern termed "fright huddle" was observed and described. Individual fish developed habitual living patterns in the channels, and smaller fish tended to occupy downstream areas.

Earliest-emerging coho enjoyed ecological advantages over later-emerging fish. The former were larger at a given time and had a greater tendency to remain in stream channels, suggesting that they have "settler's rights" to available environment and/or better feeding opportunity. The results are discussed with reference to environmental rearing capacity and volitional residence."

McCormack, Jean C.

1962. The food of young trout (Salmo trutta) in two different becks. J. Anim. Ecol. 31:305-316.

"1. The food of 0-group trout (fry) and 1-group trout (yearlings) from two becks in northern England (one on slate and the other on limestone) was investigated by examining 909 stomachs collected in the years 1957 to 1960.

2. Fry from both becks ate ephemeropteran nymphs, chironomid larvae, Gammarus and dipteran larvae, but the relative importance of each of these animals differed considerably between the becks.

3. In Black Brows Beck terrestrial animals made up a large part of the diet of yearlings; in King's Well Beck the yearlings ate the same aquatic animals as fry but in different proportions.

4. Very young fry were found to eat the same kinds of food as the older fry; the organisms eaten were not always the smallest ones available.

5. Young trout eat the same food organisms as eels and bullheads. Trout over 10 cm long eat trout eggs and alevins.

6. Trout feed even when the water temperature is below 6° C."

McCrimmon, H. R.

1954. Stream studies on planted Atlantic salmon. J. Fish. Res. Bd. Canada, 11(4):362-403.

"Plantings of Atlantic salmon fry were made in the Duffin Creek system in order to determine the survival and distribution of salmon under a variety of stream conditions. Population studies estimated that the three general June plantings resulted in an average survival of 12.7 per cent until the autumn of the first year, 9.2 per cent until the autumn of the second year. High summer temperatures were lethal to the salmon in certain parts of the creek system. Over the balance of the planted part, the greatest mortality occurred soon after plantings when heavy predation by other species of fish occurred. The extent of predation was determined largely by the amount of shelter available to the fry. Suitable shelter for the young salmon was limited generally to gravelly riffle areas where the degree of bottom sedimentation determined the amount of shelter offered. Other stream conditions were of minor or no importance in salmon survival. Further losses of salmon were low once the young salmon had become established in the creek system."

McGie, Alan M.

1970. Research and management studies on Oregon coastal salmon. U.S. Dept. Inter., Bureau Comm. Fish., Anadromous Fish. Act. Project 39-2, Annual Rept. 107 pp.

"Rearing coho are concentrated in the middle of lakes during the summer and move into the arms of lakes during winter. In late summer rearing coho in lakes are found near the bottom during the afternoon and disperse toward the surface and are randomly mixed in the water column in the evening hours. The population shifts back to the bottom during the day.

Coho in lakes grew faster initially but tapered off toward winter. Coho in streams had a more constant growth rate but it fluctuated more.

Coho fed on Zooplankton and chironomid larvae and pupae. Terrestial insects did not seem to be of any great importance (2%). Fall chinook salmon: discusses emigration time, growth rates, length, size of emigration, diel pattern of movements, competition with coho. Chinook grew slower than coho when they were together. Rate of growth of chinook appeared to be impaired by the presence of coho. Also data on growth rates of estuarine raised coho and food composition."

Miller, William H.

1968. Downstream emigration of chinook salmon fry. Idaho Fish and Game Dept., Salmon and Steelhead Investigation, Project F-49-R-6, Job Completion Rept. 16 pp.

"Tests were conducted to determine the influence of the following factors on downstream movement of chinook salmon fry: (1) density, (2) bottom type, (3) visual and physical isolation, (4) food, and (5) temperatures. Downstream movement of chinook fry appeared to be related more to temperature than any of the other factors tested."

Mundie, J. H.

1969. Ecological implications of the diet of juvenile coho in streams. Symposium on salmon and trout in streams. H. R. MacMillan Lectures in Fisheries, Univ. British Columbia. pp. 135-152.

"The requirements of the salmonid egg result in fry emerging into turbulent unproductive water. There is, therefore, a precarious balance between energy spent by fry obtaining food and the reward gained. Coho fry save energy by living close to the margin of streams. This results in loss of mid-stream foods. The holding capacity of streams may be raised by the artificial provision of marginal back eddies. The earliest meals of fry reflect the habitat on emergence and the size of the fish: later foods can be very diverse. Their analysis can be facilitated by collecting drift and emerging insects simultaneously. The correspondence between drift and diet in a 24-hr period need not be close. Where food is scarce exuviae are eaten, where plentiful, they are rejected. The food sources of the insects which make up the diet are the primary production of lakes, detritus of terrestrial origin, or its microflora, and terrestrial production. An ideal food channel would receive contributions from each of these, and have shallow fast-flowing water, narrow width, numerous areas of marginal slack water and no extremes of flow. Increased production of coho is most likely to come from measures of flow regulation ranging from simple stream management to elaborate engineering projects."

Mundie, J. H.

1971. The diel drift of chironomidae in an artificial stream and its relation to the diet of coho salmon fry, Oncorhynchus kisutch (Walbaum). Can. Ent. 103:289-297.

"The diel pattern of drifting adults, pupae, pupal exuviae, and larvae of Chironomidae in a stream was established. Emergence was trimodal for the common species (Cricotopus sp. and Psectrocladius sp.), and larval drift-rates increased almost two-fold in darkness. The concurrent diel consumption of Chironomidae by coho fry was examined. The fish appeared not to make use of the peak drift-rates of larvae. Closest temporal correspondence between drift and diet was shown by adults. Forage ratios demonstrated greater consumption of chironomids than would be expected from their proportions in the drift. The order of acceptance was pupae, adults, larvae, and exuviae. High degree of utilization of an item is attributed to flotation and visibility. The major determinants of how much food is taken from the stream are identified as: marginal residence of the fish, the occupation by the fish of slow-water feeding stations, and the visibility of food items."

Narver, David W.

1972. A survey of some possible effects of logging on two eastern Vancouver Island streams. Fish. Res. Bd. Canada. Tech. Rept. No. 323. 55 pp.

"Late summer standing stock estimates of the trout population in Jump Creek was considerably greater in the timbered (2226 fish/acre and 38.8 lbs/acre) than the logged section(1420 fish/acre and 3.9 lbs/acre). The standing stock of juvenile coho salmon and steelhead in Wolf Creek ranged from 6722 fish/acre (27.9 lbs/acre) to 10,206 fish/acre (49.8 lbs/acre) with the highest density (mainly steelhead) in the logged sections. Stock estimates for these two streams are similar or higher in comparison to other stream salmonid populations reported in the literature.

Other possible effects of logging revealed in this survey was fish size, stream temperature and stream channel width. A larger average size of each age group of trout in the logged section of Jump Creek compared to the timbered section may have been related to higher stream temperatures in June and July leading to faster development of pre-emergent fry and earlier emergence. Stream temperature in the logged sections were higher than in upstream timbered sections. In Jump Creek maximum temperature was 21.1° C (70.0°F) in the logged section and 15.1° C (59.2° F) in the timbered section; temperatures over 20° C (68° F) lasted only a few hours each day. The channel of both streams in the logged sections appeared badly eroded with cutbanks and wide gravel bars, but only in Wolf Creek was the channel significantly wider in the logged than the timbered sections."

Nilsson, Nils-Arvid.
1957. On the feeding habits of trout in a stream of northern Sweden. Rept. Instit. Freshw. Res. Drottningholm, 38:154-166.

"The stomach contents of about 300 trout, adults and fry, from the River Rensjoan district in northern Jamtland were examined.

Differences were found in the food of lake-dwelling and river-dwelling trout, the lake-dwelling trout feeding mainly on fish and insects, the river-dwelling mainly on organic drift.

Differences were found in the consumption of the food in the upper and in the lower course of the stream, the part played by the organic drift being more important in the upper course.

The fry were found to consume mainly food objects of smaller size than the adults, mostly planctonic crustaceans carried out by the current in the outflow of the lake.

The behaviour mechanism regulating the feeding of the fry is supposed to be of a simpler, more basic type than that of the adult fish.

Burbot were found to share their main bottom food, larvae of Trichoptera, with the trout, They did not, however, consume drift food to any important extend."

Otto, R. G., and J. E. McInerney.
1970. Development of salinity preference in pre-smolt coho salmon, Oncorhynchus kisutch. J. Fish. Res. Bd. Canada 27:793-800.

"When tested in a horizontal salinity gradient, freshwater-adapted coho salmon exhibited a bimodal preference response throughout most of the pre-smolt period. Preference modes were located at freshwater and at a salinity intermediate between fresh and sea water. The concentration of the higher preferred salinity changed both with time and instantaneously with the dimensions of the test gradient. Fish tested in a gradient that originated at 4‰ exhibited a single preferred salinity at 7‰ in June, which increased gradually to 13‰ by February. The same fish tested in a gradient originating at freshwater showed a corresponding preference for an intermediate salinity in addition to their preference for freshwater. However, this second preferendum was at a somewhat lower salinity than that observed in tests in which freshwater was excluded from the gradient.

With the approach of the smolt transformation, preference for freshwater was greatly reduced and the response distribution became unimodal. At no time during the period prior to the smolt transformation did the preferred salinity exceed 14‰."

Otto, R. G.
1971. Effects of salinity on the survival and growth of pre-smolt coho salmon (Oncorhynchus kisutch). J. Fish. Res. Bd. Canada 28:343-349.

"Salinity tolerance of juvenile coho salmon (Oncorhynchus kisutch) increased markedly during the period from approximately 1½ months after emergence from the gravel to the onset of the smolt transformation, except for a decline in the fall. In January, salinity tolerance ceased to limit dispersal to the sea. The limiting effects of high salinities on survival were less for larger fish than for smaller individuals and were substantially reduced by a period of exposure to dilute salinities. Growth rate, food intake, and gross food conversion efficiency had the highest values at salinities of 5-10 ppt throughout the pre-smolt period. The results are discussed in relation to the feasibility of using saltwater impoundments as a management tool in increasing coho production."

Palmisano, John F.
1971. Freshwater food habits of Salvelinus malma (Walbaum) on Amchitka Island, Alaska. M.S. Thesis, Utah State Univ. 86 pp.

"Stomach contents of 3,672 Dolly Varden char collected from September 1967 to November 1968 were examined to determine the food habits of this species. Of these, 3,100 (86%) had food in their stomachs. Aquatic invertebrates (Insecta and Crustacea) comprised over 90% of the diet. Food habits varied with habitat. Aquatic insects were most important in the diet of stream fish while aquatic insects and crustaceans were most important in the diet of lake fish. Food habits of lake fish were related to lake bottom type and access to the sea. Fish in landlocked lakes fed primarily on aquatic insects, fish, and fish eggs. In lakes with access to the sea, crustaceans, followed by aquatic insects, were the major food items in those with firm bottoms adjacent to shore while aquatic insects, followed by crustaceans, were the major food items in those with muck bottoms adjacent to shore. As fish size increased, feeding activity decreased and aquatic insects became less important in the diet while crustaceans and fish became more important. During summer, feeding activity was highest for lake fish while it was highest during autumn and summer for stream fish. Aquatic insects were the dominant food item in summer while crustaceans and fish were dominant in spring and autumn. Mature and immature fish of similar size ate similar organisms. Mature fish, however, fed more sporadically prior to spawning. Feeding activity was highest during daylight hours. Dolly Varden selected larger food items, such as insects and amphipods and ignored small items such as nematodes and oligochaetes."

Palmisano, John F. and Helm, William T.
1971. Freshwater food habits of Salvelinus malma on Amchitka Island, Alaska. BioScience 21(12):637-641.

"Of 889 fish sampled in streams, 80% had been feeding. Aquatic insects were present in 90% of the fish. Other food items were crustaceans (12%); fish and fish eggs (4%); and mollusks (2%). By volume, aquatic insects were dominant in 59% of the stomachs, crustaceans 10%, and fish and fish eggs in 3%. Aquatic insects were the basic food of fish from streams and certain types of lakes.

There was a significant difference in the percent feeding between the size classes of the fish. The smallest size class had the highest proportion of feeders. This proportion became progressively lower in each larger size class. Small fish more frequently consumed aquatic insect larvae than pupae and adults, crustaceans, fish or fish eggs. In the first four size classes, aquatic insects were dominant by volume more often than other food items. As fish size increased, however, crustaceans, fish, and fish eggs increased proportionally in the diet. This change in diet may have reflected the size of the food item that fish were able to ingest rather than the type of food item preferred.

Of the aquatic insects, dipterons were the most common insects. The midge (Chironomidae) in its three life forms was by far the most common dipteron in the diet."

Peterson, G. Ross.
1966. The relationship of invertebrate drift to the standing crop of benthic organisms in a small stream. M.S. Thesis. Univ. British Columbia. 39 pp.

"1. Coho and steelhead derived a significant proportion of their diet from groups of invertebrate that frequently occur in the drift.

2. It was inferred that predation caused a drop in drift standing crop of insects in areas of high fish density.

3. Coho fed more on drift than did steelhead.

4. The data suggest that steelhead fed more on the benthic while coho fed more on the surface.

5. Higher fish standing crops in areas where greater drift occurred."

Rankel, Gary L.
1971. An appraisal of the cutthroat trout fishery of the St. Joe River. M. S. thesis. Univ. Idaho, Cooperative Fisheries Unit.

"In recent years the size and number of cutthroat trout (Salmo clarki) harvested from the St. Joe River have declined. To discover the extent of the problem and its probable causes, I examined the life history, abundance, population structure and harvest of cutthroat trout. By comparing catch-effort, observed abundance (snorkeling counts), length and age compositions of harvest, and survival rates of cutthroat from heavily and lightly-fished river sectors, and considering recent increases in fishing pressure, the extraordinary vulnerability of cutthroat, population dynamics of the species and reports relating over-fishing and declining cutthroat stocks, I concluded that over-fishing caused the recent deterioration of the fishery."

Reed, Richard D. and R. H. Armstrong.
1971. Effects of logging on Dolly Varden. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1970-1971, Project F-9-3, 12(R-IV):105 pp.

"This report presents the results of a single season effort to determine the status of Dolly Varden, Salvelinus malma, populations along the Juneau road system by means of stream surveys, the number of Dolly Varden wintering in Auke Lake, and creel census.

A total of 57 streams and lakes is included in the analysis. Most of these systems were surveyed for species present, amount of rearing and spawning area available, and fishing potential. In addition as much information as possible from other sources is included in this analysis.

A total of 6,215 out-migrant sea-run Dolly Varden were counted at the Auke Creek Weir. Approximately 3,000 of these fish were between 10 and 20 inches in fork length. Of the Dolly Varden censused along the Juneau road system, 5.5% had spent the winter in Auke Lake. The census at Montana Creek revealed 12.7% of the catch were from Auke Lake.

Of 581 fish censused, Dolly Varden made up 88% of the total catch. The Dolly Varden catch per angler hour was 0.54.

Recommendations for research and management of Dolly Varden in the Juneau area are presented."

Ruggles, C. P.
1966. Depth and velocity as a factor in stream rearing and production of juvenile coho salmon. Can. Fish Cul., 38:37-53.

"1. Shortly after emergence in the spring large numbers of coho fry moved both upstream and downstream from their place of emergence.

2. Fry that had moved upstream after emergence tended to remain in the artificial rearing channels to a greater extent than fry that had moved downstream.

3. The amount of downstream migration was controlled, at least in part, by the availability of low velocity water. Over twice as many fry remained in a pool-like situation as in a riffle-like situation. An intermediate number of fry remained when the depth-velocity situation was somewhere between pool and riffle.

4. The addition of shade reduced the initial holding capacity of one of the experimental rearing channels.

5. The addition of cover reduced the over-winter carrying capacity of one of the experimental rearing channels.

6. Coho fry in a riffle-like environment showed strong agonistic behaviour and territoriality.

7. Coho fry in a pool-like environment showed less agonistic behaviour and territoriality.

8. More age 1 coho smolts were produced in the pool-like environment.

9. More fish food was produced in the riffle-like environment.

10. The most coho smolt production occurred in a channel composed of one-half riffle and one-half pool. This was especially evident in terms of biomass of migrating smolts."

Saunders, Richard L. and Gee, John H.
1964. Movements of young Atlantic salmon in a small stream. J. Fish. Res. Bd. Canada, 21(1):27-36.

"The locations of tagged parr and fin-clipped fry were observed from summer through early winter in a 1000-ft (328-m) study area of a small coastal stream. Tagged parr were usually found in or near places of original capture which are herein designated as homes. Parr whose homes were in pools, which appeared to be as suitable habitats as riffles, and those in adjacent riffles appeared to stay in their respective habitats. Some returned to their homes after having been moved as much as 700 ft (213 m) upriver or downriver. Fry were most numerous in shallow riffles and appeared to remain within small areas of the stream during summer but moved into parr habitats, the pools and deep riffles in autumn."

Sears, Howard S. and Meehan, William R.
1969. Short term effects of 2,4-D on aquatic organisms in the Nakwasina River watershed, Southeastern Alaska. U.S. Fish and Wildlife Service. Bur. Comm. Fish Biol. Lab. Auke Bay, Alaska 24 p (Taken from Sinha 1971).

"The Forest Service sprayed 2,4-D on logged off land on Baranof Island to control Red alder at a rate of 2 lbs/acre. There was no significant immediate mortality to fish (Coho salmon and Dolly Varden) and aquatic insects even in streams that were sprayed directly. Water samples and fish tissue samples analyzed for 2,4-D content showed conc. levels below those considered lethal."

Shapovalov, Leo and Taft, Alan C.
1954. The life histories of the steelhead rainbow trout (Salmo gairdneri gairdneri) and silver salmon (Onchorhynchus kisutch) with special reference to Waddell Creek, Calif., and recommendations regarding their management. Calif. Fish. Game, Fish. Bull. No. 98, 375 pp.

Presents information on most of the aspects of the freshwater rearing period of young coho salmon and steelhead trout.

Sinha, Evelyn
1971. Lake and river pollution - an annotated bibliography. Ocean Engineering Information Series Vol. 4.

This bibliography contains 601 INFORMATIVE ABSTRACTS of literature providing substantial scientific and technical information obtained from local and regional studies in laboratory and field investigations of lake and river pollution. These deal with the parameters of pollution and pollutants; the agricultural, atmospheric, domestic, and industrial sources of pollution and with effects of engineering activities; hydrological, geological and meterological processes involved in understanding the paths of pollutants; the effects of pollution on fishes, invertebrates including insects, macrophytes, plankton, zooplankton, bacteria, fungi, viruses and yeasts, birds, and on human health. Trends in water quality management are also considered. A bibliography of bibliographies, a detailed subject outline, a keyterm index and an index citing all authors and coauthors are included. Represented are world wide sources found in 144 journals, some 25 national and international conferences and more than 80 additional sources consisting of governmental research reports, institutional and industrial contract reports. Intended as a guide in interdisciplinary studies of lake and river pollution. Coverage 1968-1970 inclusive.

Skeesick, Delbert G.
1970. The fall immigration of juvenile coho salmon into a small tributary. Res. Rept. Fish Comm. Oregon. 2(1):90-95.

"The Fish Commission operated an upstream-downstream trap on Spring Creek, Wilson River from 1948 through 1958. Each fall an upstream migration of relatively large juvenile coho occurred. An average of 62.6% of the fall upstream migrants survived and returned downstream in the spring as smolts. The fall upstream migrants which survived to the smolt stage averaged 14 mm longer at emigration than smolts which had spent their entire lives in Spring Creek. The recapture rate of mature fish that had been fall upstream migrant juveniles was 0.3% while the recapture rate from fish native to the stream was 0.8%. I theorized that (1) the juveniles had spent the summer rearing in the Wilson River where they had grown rapidly; (2) the juveniles entered Spring Creek in the fall to escape the high, turbulent water conditions of the main river; and (3) adults, that had been immigrants, received a permanent imprint of their natal stream and had returned there rather than to Spring Creek. Observations from two other river systems are reported to substantiate the behavior pattern and suggest that other species may have similar habits. Changes in habitat management and research concepts that will be necessary, if this behavior pattern is widespread, are discussed."

Smoker, William A.
1953. Stream flow and silver salmon production in western Washington. Wash. Dept. Fish. Res. Papers. 1(1):5-12.

"The significant grouping of silver salmon catch data about the regression line established by different annual runoffs shows that for the period 1935 through 1950 the success of the commercial silver salmon fishery in western Washington has been related to the extent of the runoff in its streams."

Stauffer, T. M.

1972. Age, growth, and downstream movement of juvenile rainbow trout in a Lake Michigan tributary. Trans. Amer. Fish. Soc. 101(1): 18-28.

"Juvenile rainbow trout were examined during 1951-59 while in stream nursery areas and when migrating downstream. Their body-scale relationship was: total length (mm) = 40.6 + 2.10 scale radius (mm X107) and relationship between length (mm) and weight (g) was $W = 0.00001384L^{3.0126}$. Age composition of trout during autumn in the nursery areas averaged 68% age 0, 29% age I and 3% age II; trout in the downstream migration averaged 64% age I, 34% age II and 2% age III. Most downstream migration occurred between 21 May and 30 June, at night, on subsiding water levels and at water temperatures of 9-17 C. There was an association between numbers of juveniles and in the nursery areas and numbers of subsequent downstream migrants.

Trout grew about 76 mm per year; growth was similar to that in other Great Lakes tributaries and to growth in Pacific Ocean tributaries. Most downstream migrants in Great Lakes tributaries were age II or less, while in Pacific Ocean tributaries, most were age II and III. Time of migration was about the same in Great Lakes tributaries as in Pacific Ocean tributaries."

Sutterlin, A. M., and N. Sutterlin.

1970. Taste responses in Atlantic salmon (Salmo salar) parr. J. Fish. Res. Bd. Canada 27:1927-1942.

"External receptors located in the snout region of Atlantic salmon parr are innervated by the facial nerve and are differentially sensitive to several chloride salts ($NaCl = KCl > MgCl_2 > CaCl_2$). They are also sensitive to mineral and organic acids but insensitive to uncharged molecules such as neutral amino acids and simple sugars.

The palatine organ containing taste buds situated on the roof of the mouth is sensitive to strongly ionized as well as uncharged molecules.

The two classes of receptors differ in temporal patterns of discharge and in their susceptibility to the blocking agents Hg^{++} and Pb^{++} and the potentiating agent Cu^{++}.

Salmon parr can detect Hg^{++} in concentrations lower than other divalent cations as judged electrophysiologically; food pellets treated with dilute solutions of Hg^{++} are rejected by the fish.

As chain length increases in the aliphati acid series the compounds become increasingly stimulatory as measured by nerve discharges in the palatine nerve.

Inert carriers treated with aliphatic acids of increasing chain length become increasingly preferred by salmon, and carriers treated with valeric and caproic acid are ingested.

Anosmic fish are capable of discriminating chemically treated carriers in a way similar to fish in which the olfactory organ is intact.

The cellular nature of external receptors of the snout is uncertain; the possibility that they are neuromasts is discussed."

Ware, D. M.
1971. Predation by rainbow trout (Salmo gairdneri): the effect of experience. J. Fish. Res. Bd. Canada 28:1847-1852.

Rainbow trout (Salmo gairdneri) provided with unfamiliar palatable food changed several components of their feeding behaviour and demonstrated that they can develop searching images for specific prey. Naive fish required an average of 4 days of experience, each of which consisted of exposure to six food particles, before they approached novel prey. After this time the distance from which trout attacked food improved and had doubled by the 12th day of exposure. When conditioned animals were deprived of experience for 90 days, the distance of reaction fell back to the initial naive level. The relation of these results to current work on searching image formation is duscussed.

Wagner, H. H., Conte, F. P., Fessler, J. L.
1969. Development of osmotic and ionic regulation in two races of chinook salmon (Onchorhynchus tshawystcha). Comp. Biochem. Physiol. 29:325-341.

"1. The development of the hypo-osmotic regulatory system was followed in juvenile fall and spring chinook salmon while in the freshwater environment. The experimental animals were exposed to sea water of various salinities by immediate or gradual transition. Measurements of survival and changes in the osmotic and ionic properties of the blood were made following exposure to sea water.

2. The ontogeny of hypo-osmoregulation appears to be similar for individuals in both races.

3. The rate of development of hypo-osmoregulation is influenced by prior acclimation to waters of lower salinity and by the growth of the experimental animals."

Warren, Charles E., Wales, Joseph H., Davis, Gerald E., Doudoroff, Peter.
1964. Trout production in an experimental stream enriched with sucrose. J. Wildl. Mgmt. 28(4):617-660.

"From 1960 through 1963, three experiments were performed on the production, food habits, and food consumption of coastal cutthroat trout (<u>Salmo</u> <u>clarki</u> <u>clarki</u>) in sucrose-enriched and in unenriched sections of Berry Creek, a small woodland stream in the Willamette River Basin of Oregon. These experiments were part of a general investigation of the trophic pathways through which energy from light, organic debris, and dissolved organic matter enters into the production of fish and other organisms. The flow in a 1,500 foot portion of Berry Creek was controlled by means of a diversion dam and a bypass canal. Four sections of this portion of the stream, each consisting of a riffle and a pool, were separated by fine screens which prevented the drifting of fish-food organisms from one section to the next. The water in two sections was continuously enriched by introducing a few milligrams of sucrose per liter, and most of the deciduous forest canopy was removed from one of the enriched and one of the unenriched sections. Only the enrichment with sucrose led to large and consistent increases in food consumption and production of trout: food consumption was increased about twofold and trout production usually much more than sevenfold. Trout production increased so much more than food consumption because only a relatively small portion of the comparatively large amount of food consumed in the enriched sections was required for maintenance of the trout stocks. The maintenance food requirements of the trout in the four sections usually were not materially different, but most of the food produced and available in the unenriched sections was required for maintenance, with little left for promoting growth. Food consumption values are believed to be more reliable measures of the relative productivity of the different sections for trout than are production values. Results of studies of food habits of the trout and available data on biomasses of insects in the riffles indicate that increased food consumption and production of trout in the enriched sections were made possible by greater abundance of aquatic food organisms, especially of tendipedid (chironomid) larvae, the consumption of terrestrial food being roughly equal in all sections. Introduction of sucrose resulted in growth of the bacterium <u>Sphaerotilus</u> <u>natans</u>, a slime organism frequently associated with organic pollution. This bacterial growth provided food and habitat for tendipedid larvae, the most important food organisms of trout in the enriched sections. Concepts of trophic relations in aquatic ecosystems and the application of these concepts to problems of water resource management are discussed in the light of the findings."

Waters, Thomas F.

1969. Invertibrate drift-ecology and significance to stream fishes. Symposium on salmon and trout in streams. H. R. MacMillan Lectures in Fisheries. Univ. British Columbia. pp. 121-134.

"Many species of invertebrates, though not all, exhibit high rates of downstream drift in a diel periodicity. Most are night-active, for whom light intensity is the phase-setting mechanism; but some species are day-active, for whom water temperature may be the phase-setter. Diel patterns consist of one or more peaks, occurring at various times of the 24 hour period depending on species. Magnitude of the drift appears to be a function of water temperature, current velocity, stage of life cycle, and population density and growth rate.

The direct significance of invertebrate drift to stream fish is in an apparent increase in availability as food. Whereas stream salmonids utilize drifting invertebrates as food to varying degrees, a substantial proportion of the diet is also gained by bottom foraging."

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Prepared by:

Steven T. Elliott
Fishery Biologist

Richard D. Reed
Fishery Biologist

Approved by:

s/ Howard Metsker
D-J Coordinator

s/ Rupert E. Andrews, Director
Division of Sport Fish